Visualisation of Tranquillity in a New Zealand National Park Setting

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Abstract

The tranquillity in national parks is currently under threat from intrusion of anthropogenic noise of a growing tourism industry and activity related to park management. This compromises the experience generally sought in national parks and conservation areas, and traditional restorative values they have to offer. This was addressed by creating informative tranquillity maps. These find application as decision making tool. Tranquillity of an area can be assessed using TRAPT, which has been developed and refined for assessing urban green spaces, national parks and wilderness areas in the United Kingdom. The subjective response to helicopter noise levels of a sample group of 35 people representing the general New Zealand population was obtained, based on visual and audial stimuli that were collected in Aoraki/Mt Cook National Park. These results were used to produce a revised TRAPT equation, representative of the New Zealand national park context. It was discovered that levels under 32dBA correspond to an excellent level of tranquillity (TR ≥ 8). This threshold was used to produce a noise level exposure calculation of both national parks in AEDT, modelling 423 flights from aircraft over a standard operational day. Contours representing tranquillity duration were then plotted as static and interactive web maps, to serve as a planning tool for park management. Results from the subjective testing indicate that noise level is a significant predictor of tranquillity. The general New Zealand population responded differently compared to the United Kingdom population as reported in previous investigations, though factors that can explain these apparent differences are examined. The tranquillity maps indicate that there is a spatial relationship between areas of reduced hours of tranquillity within close proximity to a larger number of flight operations. Topography is also a factor that has a strong influence on noise propagation from helicopters, which effects the tranquillity of a place.

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1. Introduction

1.1 Anthropogenic Noise in National Parks

Anthropogenic noise in New Zealand national parks has been identified as a growing issue by The New Zealand Department of Conservation (DoC). An increase of domestic and international park visitors has resulted in a corresponding demand that their diverse expectations are catered for (DoC 1996). Tourism operators along with DoC use mechanised transport to improve accessibility to areas otherwise only accessible by foot. The anthropogenic noise produced by these operations have an adverse effect on amenity values in national park settings, highly valued for their natural character and tranquillity (Office of the Parlimentary Commissioner for the Environment 2000). The Resource Management Act (RMA) 1991 allows territorial authorities to regulate activities on land and water that affect amenity values such as tranquillity, yet at present, it does not enable the authorities to control noise from airborne activities. In particular, DoC allocates rights for aircraft to land within national parks (Espiner and Wilson 2015), but does not specify flight paths. Natural areas that are accessed by aircraft also, by default, give them primary allocation of the natural soundscape and render it compromised to other visitors. Very little noise energy is required to substantially degrade listening conditions when the natural sound levels are already very low (Hatch and Fristrup 2009)- and such environments must be vigorously protected, as they are the most vulnerable to intrusion of noise.

Producing effective maps of tranquillity ratings in national parks can be a tool to aid national park management to better negotiate and develop policy for the protection of the natural setting. Factors that have been identified as statistically significant that affect the tranquillity of a place include the level of noise (L_{Aeq}, L_{Amax}, and other metrics that will be later discussed in section 1.3) and the percentage of natural and contextual features in the visual scene (Watts and Pheasant 2013). The Tranquillity Rating and Prediction Tool (TRAPT) has been designed to predict how on average visitors feel about their immediate environment using the aforementioned statistically significant factors (Pheasant, Horoshenkov et al. 2010). This investigation looks into visualising the effects of anthropogenic noise pollution caused by helicopters in Aoraki/Mt Cook and Westland Tai Poutini national parks in the form of tranquillity maps based on the New Zealand content using rated perception of tranquillity of a New Zealand population sample.

National Parks

About one-third of New Zealand's land area is under some form of environmental protection. This is more than in any other country (Taylor 1997). Most of this protected area consists of 13 national parks. United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites include Tongariro National Park, in the North Island (Hall and Piggin 2002), and Westland Tai Poutini, Aoraki/Mt Cook, Mt Aspiring and Fjordland National Parks in the South Island (UNESCO 2002).

DoC visitor surveys suggest conservation to be increasingly important on the personal level. 85% of respondents believe that their connection with the New Zealand natural environment improves their lives (IPSOS Limited 2016). Protected natural areas with little to no anthropogenic noise can provide an exceptional opportunity to perceive and identify natural sounds, and expand auditory horizons (Fristrup, Joyce et al. 2010).

Legislation

The National Parks Act (1980) aims "*to preserve parts of the country that contain scenery of such distinctive quality, ecological systems, or natural features so beautiful, unique, or scientifically important that their preservation is in the national interest*". These areas of conservation have been managed by DoC since 1987, their role includes preserving national parks for their intrinsic worth and for the benefit use and enjoyment of the New Zealand public. The Conservation Act (1987) delegates to DoC the task of "*allowing tourism on conservation land, providing the use is consistent with the conservation of the resource*".

Tourism

International visitor numbers increased from 2.8 million to 3.2 million (a 14.3% increase) between 2014 and 2016 (Tourism Industry Aotearoa 2016). This growth is forecast to continue (Ministry of Business Innovation & Employment 2017). Domestic tourism still makes up the majority of the tourism market with 59% of total visitor expenditure (Tourism Industry Aotearoa 2016). This contribution is especially important during non-peak times of year.

New Zealand is widely promoted as a tourism destination through the successful advertising campaign '100% Pure New Zealand' (Tourism New Zealand 2018), which sells a story of the country's combination of landscapes, people and activities that make it a unique experience that cannot be found anywhere else in the world.

An undeniable attraction in itself is the natural environment**.** International tourists visit between one and two national parks while staying in New Zealand, and three if they have the intention of walking or tramping (Toursim New Zealand 2017). The natural environment is also valued by the domestic population, with approximately 41% of New Zealanders having visited a DoC recreational area between 2015 and 2016 (IPSOS Limited 2016), and of these domestic visitors, the most popular activities carried out were taking a short walk for less than three hours (58%) or sightseeing (51%).

New Zealand national parks have many unique attractions including Aoraki Mt Cook, the tallest mountain in Australasia, and several large glaciers. The Fox and Franz Josef glaciers, in Westland Tai Poutini National Park, are popular tourist attractions. These glaciers are receding at an increasing rate (Purdie, Anderson et al. 2014) and this is expected to continue into the future (Purdie 2013). It can be argued that this is contributing to an increase of visitor numbers through resultant promotion of 'last chance tourism' (Wilson, Stewart et al. 2014).

Helicopter Activity

Anthropogenic noise from a range of activities in national parks is expected to deteriorate the tranquillity of the natural setting. However, in the cases of Westland Tai Poutini and Aoraki Mt Cook national parks, helicopters are acknowledged to be the predominant anthropogenic noise source. Particularly in the glacial valleys of Fox, Franz, and Tasman.

A range of helicopter-related activities in the region are offered by tourism operators, from scenic overflights, to glacier landings, and guided heli-hikes. DoC is tasked with the role to oversee landing (and hovering) concessions for commercial operations (New Zealand Government 1987) but not overflights.

Glacier activities are a major attraction to the park, however since a large collapse of the terminal section of Franz Josef Glacier in 2012 and out of concerns for personal safety (Wilson, Stewart et al. 2014), safe access to walk on the glacier is only attainable by way of helicopter. Similarly, access to Fox Glacier has been permitted only through helicopter landings since 2014 (Espiner and Wilson 2015), leading to an increased number of landing concessions for operators offering glacier experiences.

One such operation is active between the Franz Josef Township and the glacier. Helicopters are expensive to operate and have limitations of customer capacity. As the trip becomes shorter in duration, it becomes less expensive to run and greater numbers of passengers are able to be carried during a standard operational day (Purdie 2013). There is therefore an incentive for a larger number of short-duration flights.

An immediate consequence of increased flying activity in and over national parks is the negative impact it has on those visitors who do not intend to fly. Overseas research found scenery to be more meaningful to people when there is less anthropogenic noise (Reid and Olson 2013), as lower noise levels help visitors experience natural sounds and wildlife.

From a series of visitor questionnaires performed in Franz Josef and Fox valleys, it was found that approximately two thirds of participants (68.3%) were against increasing the number of helicopter flights to allow more people glacier access, and 66.8% agreed that 'access to the glacier should remain as it is now' (Espiner and Wilson 2015). At Fox Glacier, 1210 annual flights were documented in 2013, and the number has grown to 2849 in 2015, reflecting the increase of visitor annoyance levels at Fox Glacier from the biennial surveys (Espiner and Wilson 2015).

Due to the high volume of aircraft activity in the glacial valleys, DoC have displayed signs (Figure 1.1) to notify visitors to expect helicopter noise, or to visit during off-peak hours to avoid it.

Figure 1.1: Franz Josef Valley Notice Board

Although scenic aviation tourism has existed since the early 20th century, its recent growth is challenging existing backcountry culture. Walking in and 'roughing it' is a traditional expectation for many New Zealand backcountry outdoor recreationalists (Cloke and Perkins 2002), as well as a portion of international visitors to whom backcountry recreation has an appeal. The Federated Mountain Club (2018) of New Zealand is a group that holds such a perspective, favouring ideas such as a minimum height ceiling for aircraft operations in national parks, and wherever possible prioritising conservation and recreation over commercial tourism.

1.2 Health

Anthropogenic Noise

Environmental contamination by anthropogenic noise is largely a result of urbanization and modernisation of technologies (The World Health Organisation 2011). The concurrent increase in anthropogenic noise has caused natural quiet to become an ever scarcer resource, of which it is argued is as important a resource as clean water, clear air and wildlife (Lee 1994, Berglund, Hassmén et al. 1996).

There is overwhelming evidence that exposure to anthropogenic noise has adverse effects on the physical and mental health of a population (The World Health Organisation 2011). Prolonged anthropogenic noise exposure contributes to sleep disturbance (Memoli and Licitra 2012), cardiovascular disease (Gramann 1999) (Wunderli, Pieren et al. 2016) obesity and diabetes (May Wen Ong 2017), cognitive impairment, hearing impairment (Clark, Head et al. 2013), high blood pressure (The World Health Organisation 2011) and Ischemic Heart Disease (van Kempen, Kruize et al. 2002). If exposed to intense levels of noise ears can suffer temporary or even permanent damages leading to complete deafness (Kuttruff 2006).

It is found that, due to the aforementioned contributing factors, associated costs to public health care are increasing (Campaign to Protect Rural England 2006). Anthropogenic noise pollution is among the most serious environmental issues currently faced by countries in the Organisation for Economic Co-operation and Development (OECD) (Hamilton 2003).

As a counter measure, noise control strategies of various forms are therefore rather common in populated areas worldwide. For example, all cities within the European Union that have over 100,000 inhabitants are required to prepare a noise control plan every 5 years (Bohatkiewicz 2016), and in addition, strategic noise maps have been applied to all major roads during the same yearly intervals - since 2007 (Alférez, Vanhooreweder et al. 2013).

An integral part of establishing sound noise control strategies includes modelling anthropogenic noise due to land-based traffic, operations at airports, construction and other urban functions. The models are used to generate strategic noise maps (Manvell 2012, Gulliver, Morley et al. 2015), and GIS tools are almost always applied in these situations, where spatial visualisation is invaluable in helping to address the noise situation in an area.

Traditionally a greater focus has been directed towards monitoring anthropogenic noise in urban centres (where people spend most of their time, between home, work, and other day-to-day involvements) compared to that for the rural or wilderness counterparts.

The passing of the United States of America's 1987 National Parks Overflight Act (1987) has led to an increased interest in the impact of noise on visitors in conservation areas. Subsequently, this has become, a more active area of research for protected areas around the world, including New Zealand (Harbrow, Cessford et al. 2011). A rapid growth of the tourism industry in New Zealand through the 1990s has further led to concerns about the impacts that tourism has on the natural environment generally.

Greenspace

A universally agreed upon measure that has a positive influence on a population's health is exposure to nature, which has been shown to reduce blood pressure, reduce heart attacks, increase mental performance and soothe anxiety (Campaign to Protect Rural England 2006, Burls 2007) reinforcing the importance of preservation of national park soundscape. Furthermore, natural environments promote reduction of stress and may have long-term physiological benefits (Tyrväinen, Ojala et al. 2014). These symptoms are strongly correlated with stress, which reduces the body's ability to resist illness and may adversely affect our metabolism (Campaign to Protect Rural England 2006). This progressive field of research is encouraging urban planners to redesign urban centres to accommodate attractive green spaces that are accessible to its citizens (Grahn and Stigsdotter 2003, Watts, Miah et al. 2013). Similarly, the importance of conservation areas are increasingly valued (Conrad, Christie et al. 2011, Lynch, Joyce et al. 2011).

1.3 Acoustic Parameters

Sound propagation is the transmission of acoustical energy through vibrating particles (Reed, Boggs et al. 2010). Sound waves can also transfer between mediums, in which the acoustical energy will either be reflected or refracted (Kuttruff 2006). In an outdoor environment, sound propagation can be complex when considering soundwave directivity between different mediums, including atmospheric effects and porosity of different ground types. Given the right terrain conditions, sound energy can be amplified if concentrated into a space, or reduced behind obstructions (Hansen 2005). Fortunately with current computing technologies, sound propagation in an outdoor environment can be modelled to an acceptable and reasonable degree of accuracy.

The human ear has a remarkable dynamic range so observation of noise levels on a linear scale is inconvenient (Bies and Hansen 2009). The acoustical index known as sound pressure level (SPL), is a logarithmic scale of sound pressure and is a better way of objectifying a measured level of sound and has the units of decibels (dB) (Kuttruff 2006).

Frequency (Hz) is the maximum number of times per second that a wave passes a point (Barber, Crooks et al. 2010). The more waves that pass per second, the higher the frequency. The human ear is not equally sensitive to all frequencies of the audible sound spectrum (Mӧser 2009) and to compensate for this, measurements of environmental noise are commonly performed using an A-weighting (expressed as the unit of A-weighted decibels, or dBA). A-weighting, which is a filter that devalues the frequencies below 1,000 Hz and above 5,000 Hz- to better conform to the human ear's decreased sensitivity (Mӧser 2009). In New Zealand the two commonly used national standards pertaining to the measurement and assessment of environmental noise are NZS 6801 and NZS 6802 , and NZS 6807 specifically for planning helicopter landing areas.

Any soundscape must be defined by at least the two following concepts – the sound perception with respect to the background and how long that sound is present (Miller 2009). For environmental noise monitoring, the duration of a noise is often assessed using the widely-used metric referred to as the L_{Aeq}. The L_{Aeq} represents the A-weighted equivalent continuous sound pressure level of a fluctuating sound (Licitra 2013). The main drawback in its use however is that it measures an average reading over a designated period of time, which may include periods of irregular noise activity.

For assessing noise from aircraft operations (particularly near airports), the metric commonly used is 'time-above' (denoted as TA), where the total time or equivalent percentage of time that an A-weighted noise level exceeds a certain threshold is measured (Minneapolis Saint Paul Metropolitan Airports Commission 2014). This metric is best applied when modelling environments where ongoing exposure to anthropogenic noise such as aircraft is likely to be an issue. This is because regardless of sound pressure level, noises can be more tolerable to humans in small doses when compared to continuous noise at the same level (Foster, Hall et al. 2000).

2. Literature Review

2.1 Tranquillity

A tranquil place is a quiet, peaceful, and attractive setting, a quality place to get away from "everyday life" (Herzog and Bosley 1992). The perception of tranquillity is conditioned by more than one stimulus type, combining inputs from two of the more dominant human senses: sight and hearing (Pheasant, Horoshenkov et al. 2010). Rating the tranquillity of a place can be useful for evaluating it's restorative value, and, in the context of a protected area, work as an effective decision making tool to prioritise amenity values (Pearse, Watts et al. 2013).

Tranquillity as a measure is subjective, however there is consensus of elements that either enhance or detract from the tranquillity of a place. Viewing physical features such as water with smooth surface textures, vegetated fields, forests, or misty mountains can improve the perception of tranquillity (Herzog and J. 1999). In the determination of tranquillity, contextual features are also of importance, and can best be described as man-made structures or places of spiritual or historical significance that directly contribute to the visual context of the urban environment (Watts and Pheasant 2015). Sounds that have been found to enhance tranquillity include those from insect and bird song, or sounds from flowing water (Watts and Pheasant 2015), whereas most forms of anthropogenic noise deteriorate the perceived tranquillity of a setting.

2.2 Tranquillity Prediction

A number of previous tranquillity studies has led to the development of TRAPT. The tool enables prediction of tranquillity at any place within an area of investigation, given some known variables. Perceived tranquillity in a setting depends on three variables, but Axelsson et al. (2010) and Gramann (1999) argue that those that are statistically significant include:

- The percentage of natural and/or contextual features
- The level of anthropogenic noise

Two variations of the model exist: the initial version for predicting tranquillity in an urban setting (Watts, Pheasant et al. 2011) and a revised TRAPT for predicting a tranquillity rating (TR) in a national park setting (Watts and Pheasant 2015). To determine tranquillity using the latter TRAPT, the equation is:

$$TR = 10.55 + 0.041NCF - 0.146L_{day} + MF \qquad (1)$$

where

- TR is the predicted tranquillity rating on a 0 to 10 scale, from minimum to maximum tranquillity, respectively (Pheasant, Horoshenkov et al. 2010). In rare cases, the calculated tranquillity rating can be negative due to the linear regression technique used to relate the variables. In this situation, the calculated value is set to 0. Similarly, when the calculation result is higher than 10, the TR value is set to 10.
- NCF represents the percentage of natural or contextual features in the given setting. The benefits of natural or contextual features in an immediate visual scene and their quantification was first proposed by Pheasant et al. (2010).
- L_{day} is the sound pressure level representing exposure over a specified time period, e.g. an A-weighted 10-hour period (8:00am – 6:00pm).
- MF represents any moderating factors that can influence the score. In previous studies, it was shown that litter, graffiti, or the presence of other people decrease the TR (Pheasant, Horoshenkov et al. 2010). The moderating factor is a minor adjustment and is unlikely to influence overall TR by more than 1 scale point.

Areas where the overall percentage of natural and/or contextual features in view is high and measures of anthropogenic noise levels are low would be given a high tranquillity rating. Conversely, areas featuring fewer natural or contextual elements in the field of view and higher levels of anthropogenic noise would return a tranquillity rating at the lower end of the scale.

2.3 Model Calibration

Previous studies that have been carried out in the United Kingdom have successfully used TRAPT based on the British people's perspective of tranquillity. Since different populations may act differently due to differences in cultural or sociological perspective (Pearse, Watts et al. 2013), this present research aims to calibrate the TRAPT equation (1) so that it reflects the subjective assessment of tranquillity as determined by the New Zealand population. The methodology of calibration is described below in section 3.1.

2.4 Applications of GIS

Modelling of anthropogenic noise has already been used as a common approach in urban areas, but also for areas under some form of environmental protection. Calculations of anthropogenic noise can significantly aid national park managers and policy makers – and in turn advance scientific understanding of park ecosystems (Fristrup, Joyce et al. 2010). Very detailed studies monitoring noise levels in national parks in America (Lynch, Joyce et al. 2011) and New Zealand (Harbrow, Cessford et al. 2011) have taken place, all using purpose-built, specific software packages for acoustic calculation through GIS(Reed, Boggs et al. 2012, Keyel, Reed et al. 2017). There is also a noticeable direct focus on anthropogenic noise impacts on animal wildlife (Keyel, Reed et al. 2017) as well as to aid park visitors (Gramann 1999)

Essentially tranquillity mapping is an extended stage to traditional noise mapping. In this case, if the noise metric levels are substituted into TRAPT, ratings can be visualised in contour bands at any location where the percentage of natural or contextual features is known. In a national park context, it is widely assumed that the percentage of natural features in view will be high, either at or close to 100% of the field of view

2.5 Research Rationale

The methods of anthropogenic noise management in national parks is a current concern (Carroll 2018, Mitchell 2018). Previous approaches of national park management have been guided by visitors' degree of annoyance (Harbrow, Cessford et al. 2011). Tranquillity is considered an appropriate measure of the environmental impact of anthropogenic noise. Perception of tranquillity at a place depends on a number of factors, but those that have emerged as statistically significant are presence of natural or contextual features in a setting, and level of anthropogenic noise. Combining subjective and objective factors in the same model, tranquillity predictions are to contribute in both a meaningful and measureable means to assess anthropogenic noise impacts in national parks (Watts and Pheasant 2015).

Previous studies of tranquillity using TRAPT have mainly focussed on anthropogenic noise from road and rail transport. This investigation seeks to expand on this previous work by shifting focus to other anthropogenic noise sources such as helicopters to New Zealand national parks.

3. Methodology

The methodology of this investigation entails a series of steps that work towards an end result of tranquillity maps of Aoraki/Mt Cook and Westland Tai Poutini national parks. The methodology can best be described as three phases: making an assessment of tranquillity according to the New Zealand population, performing a noise calculation model on national parks, and developing tranquillity maps using GIS. The first phase was adopted from a similar investigation into Westland Tai Poutini National Park (Nicolls 2016) and both the first and second phase are based on the methodology of Watts & Pheasant (2015).

3.1 Calculation of Tranquillity

3.1.1 Ethics

The concept of tranquillity rating is based on subjective assessment of recorded sounds by a participants chosen on a demographic basis to represent the general New Zealand population. The process involves human subjects and so ethics approval is required for independent assessment of the risks, safety, and ethics involved in collection of data. Ethics approval was granted on 15 August 2017 by the University of Canterbury Human Ethics Committee (see Appendix A). The parts of the investigation concerning ethics were graded as low risk, and were completed in accordance with the ethics approval.

3.1.2 Reported Tranquillity Questionnaire

A perceived tranquillity questionnaire (see Appendix F). was adapted from a previous United Kingdom tranquillity investigation (Watts and Pheasant 2015). All other factors such as naturalness, remoteness, pleasantness and calmness were deemed not important and subsequently removed, as tranquillity is the fundamental focus for this investigation.

3.1.3 Field Data Collection

Sound measurements and corresponding recordings were obtained in the field at Aoraki/Mount Cook National Park on the 16th June 2017. Prior acknowledgement of Tōponui sites that are sacred to Māori meant they would not be included as locations to collect data. A B&K type 2250 sound level meter (SLM) was used for the measurement of sounds and the corresponding recordings were saved onto a secure digital SD card.

Prior to making measurements and taking recordings of subjects at each site, the SLM was calibrated using a B&K type 4231 Sound Calibrator. The calibration tone was also recorded so that it could be used as the reference sound file against which to produce identical output levels in later listening room tests as the level at which recordings were made in the field. Except for the microphone calibration check, a windshield was used for all following measurements and recordings.

Using the frequency analyser advanced template, eleven sound measurements and recordings were taken at four sites (Figure 3.1). Three main subjects of recordings were targeted:

1. Helicopter noise at various positions of flight
2. Natural ambient environmental sounds without presence of any anthropogenic noise
3. A combination of (1) and (2)

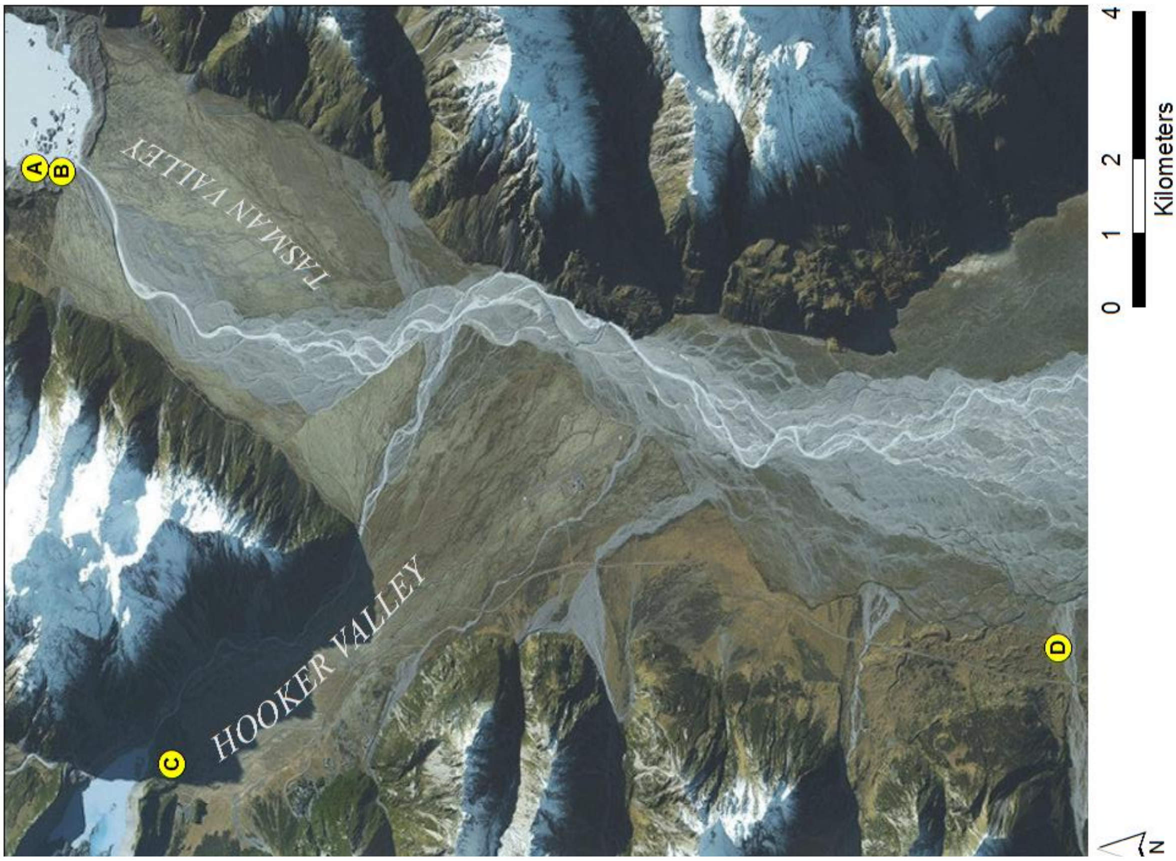

Figure 3.1: Locations of Measurements

Following the practice described in NZS6802 , measurements and recordings were taken with an A-weighting to best resemble the response of the human ear to sounds at mid-frequencies (B&K 2016). The measurements varied in length, based on conditions such as the duration of a helicopter fly-by. The SLM was left to record for several minutes to ensure a good quality reception of natural background noise. All measurements were recorded with the SLM mounted on a tripod set at the height of an average human ear, and a distance of two meters was kept between the researchers and the SLM for most of the duration of the measurements.

Additional information, such as the location of GPS (Geographic Positioning System) measurements, wind speed, cloud cover and any other observable weather patterns, were recorded at the same time as the acoustic measurements and audio recordings. Videos of the landscape were recorded at sites A and D in figure 3.1, using an iPhone 6s (set at 4K resolution) mounted on a tripod.

3.1.4 Field Data Processing

The sound measurements from the SLM were copied into an archive on B&K BZ-5503 Measurement Partner Suite, while the audio and video recordings were stored and backed up in the Windows file explorer library.

The software suite Audacity (2.1.3) was used to refine the eleven recorded audio clips into 30, 10-second truncated files and any contamination of other sound sources such as voices or footsteps were removed. The truncated files were further modified to fade in and out by 0.1 second in consideration for participant comfort. The sound pressure levels of the 30 truncated files were then calculated using digital post processing in B&K Pulse Reflex (17.1.1), and compared with real-time analysis in B&K Pulse LabShop Fast Track (17.1.1).

The 30 truncated files were refined to a selection of ten, ensuring the range of sound pressure levels was a reasonable representation of spread: of what levels were measured in the park.

The ten truncated audio files together with the visual stimuli were then made into 70 compilation videos using Adobe Premiere Pro 2018 CC (12.1.1). The randomised order of the audio files was determined using multiple 10 x 10 grid cell Latin square matrix distributions. Lastly, the compilation videos were designed to feature a 10-second countdown timer at the beginning to prepare participants for testing.

Figure 3.2: Visual Stimulus for Tranquillity Testing

The audio stimuli were played as 10-second clips interspersed with 10-second quiet intervals. The visual stimulus was a 10-second video loop recorded at location A (refer to Figure 3.1), looking out over Tasman Lake (Figure 3.2). During the quiet intervals the video was edited to have extremely low brightness and be out of focus in order to prompt participants that immediate attention was not necessary.

3.1.5 Participants for Sample Population

Participants were gathered through means of online advertising and physical flyers posted around the University of Canterbury campus (see Appendix B). To represent the perspective of tranquillity of the general New Zealand population, the group of 35 was selected with a range of individuals that reflected age and gender distributions from the 2013 Census (Statistics New Zealand 2013).

3.1.6 Testing Setup

The listening booth located in room 801 of West (Formally Rutherford) Building at the University of Canterbury were set up to test individual participants on their perceived tranquillity associated with various stimuli. The listening booth used is IANZ accredited for the testing of hearing protectors (AS/NZS 2002) and as such provided a quiet, uniform, uninterruptable environment where participants could give their entire focus to the assessment of tranquillity.

A calibration exercise of audio stimuli was performed before the testing phase. This was required in order to ensure that the audio of the test video was played at the exact sound level that was measured in the field environment. To achieve this, a 1 kHz calibration tone was played using Windows media player (12), with the audio feed being played through a set of Sennheiser HD 215 headphones that were fitted on a B&K type 4100 Head and Torso simulator, connected to the same computer that was running B&K Pulse Labshop (see Figure 3.3). The volume output control on the computer was adjusted to 94.3dB to match the calibration tone. This procedure was repeated every morning before testing participants, or whenever the computer entered sleep mode between tests.

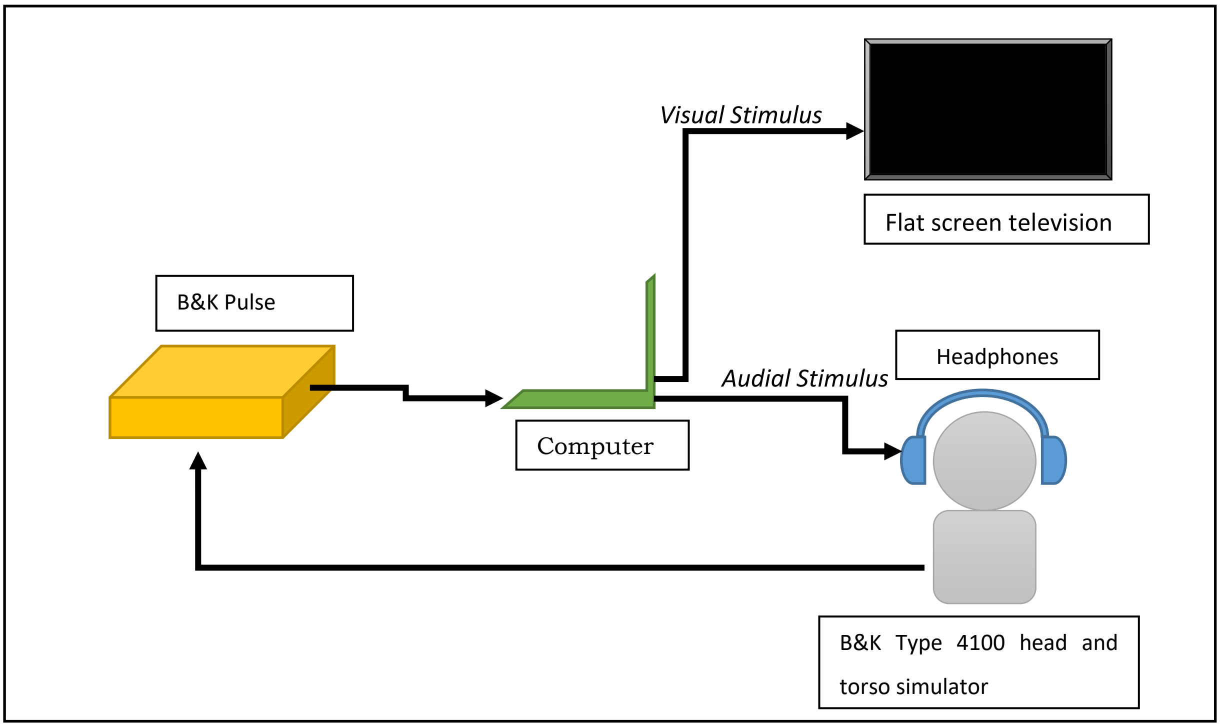

Figure 3.3: Tranquillity Testing Setup

3.1.7 Participant Testing

Individual participants were asked to sit behind a small desk facing a 55" Sony Bravia 1080p flat screen television. Sennheiser HD 215 headphones were placed over the ears of the participant, and the tranquillity questionnaire and pens were set on the desk. Participants were briefed on the test structure and asked to imagine they were experiencing the national park first hand, and then left in isolation with minimal distraction. The perceived tranquillity test was performed by playing the compilation videos via the calibrated computer, with the audio stimuli feed being sent through the headphones, and visual stimuli being projected onto the flat screen television. The layout of the listening booth can be seen in figure 3.4.

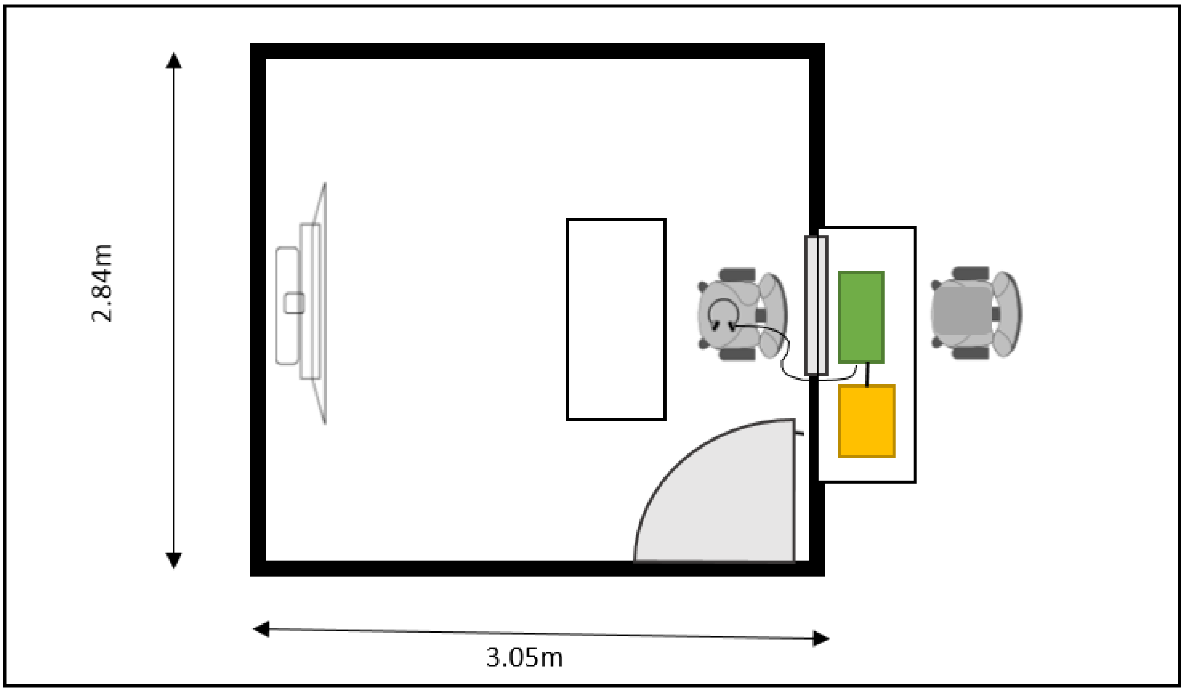

Figure 3.4: Tranquillity Test Listening Booth

Each participant was played three compilation video files, with the order determined by a Latin square matrix. The first video file was designed as a practice run through in order for the participants to familiarise themselves with the range of audio stimuli. Once the video file was played, the researcher entered the room to ensure the participant understood the task and completed the corresponding questionnaire page. This process was then repeated two more times. Participants were rewarded with a university café voucher.

3.1.8 Results Processing

The reported tranquillity of each stimulus of the second and third compilation video files played in the test sequence was averaged for each participant. The reported tranquillity of each stimulus was averaged again for the entire sample population. These averaged results of reported tranquillity were then compared to the measured L_{Aeq} of each of the 10 audio stimuli in a scatterplot graph, the relationship of which could be used to represent the general New Zealand populations' perspective of tranquillity in national parks. Both linear and fourth-order polynomial trend lines were observed to determine the nature of the tranquillity scale applied to the general New Zealand population, and the line equation representing the linear relationship was then used to create a revised TRAPT equation.

3.2 Calculation of Noise using AEDT

3.2.1 Data Collection and Initial Processing

A 15x15 metre resolution Digital Terrain Model (DGM) was sourced from Koordinates, originally recorded by the University of Otago National School of Surveying (2011). The geographic projection and terrain file format type were changed accordingly to ensure AEDT compatibility.

Flight records were taken by GPS recorders installed into helicopters of participating companies that operate in the parks. Each helicopter follows a flight path designated to a certain advertised product. As to be expected, the sky has virtually limitless boundaries so no flight is exactly the same. To compensate, the individual products were grouped into common flight 'corridors' to minimise later processing longitude and latitude flightpath coordinates were averaged, as well as horizontal aircraft speed, and vertical elevation.

3.2.2 Metrics and Environmental Conditions

Two calculation metrics were used in this investigation: L_{Amax} (maximum A-weighted level) and TA (A-weighted time-above a threshold level).

The usage of L_{Amax} was only used in the preliminary stages to verify the model calculation, as this metric can run in a short period of time without the need of advanced computational processing hardware. The shortfall of this metric is only the peak level is measured, which is a poor representation in the case of multiple operations during a typical day, where ongoing exposure of anthropogenic noise is predominant issue.

For this reason, the time-above (TA) metric is a more relevant assessment criteria for national park tranquillity levels over the duration of a day, as the total amount of time or equivalent percentage of time can be calculated, that a designated A-weighted threshold sound pressure level is exceeded.

A grid of noise-receiver points was set to be overlaid on top of the DGM, and as a noise source a Eurocopter AS350 Écureuil helicopter was selected from the AEDT aircraft library, a type of helicopter that is commonly used by New Zealand tourism operators.

The parameter for weather in AEDT was left to its default setting, which assumes a standard atmosphere.

3.2.3 AEDT Model Verification

In order to check that AEDT produced satisfactory results, some preliminary calculations were compared to a procedure laid out by Falzarano and Levy (2007) of manually calculating sound radiation by spherical spreading. The sound power of a Eurocopter AS350 Écureuil helicopter, determined at 33 m, was obtained from the AEDT aircraft library. Six receptors were arranged in a line that transects the position of a helicopter, and distances were obtained through finding the difference between ground coordinates and elevation of the helicopter and each receptor. The outwards noise propagation from the source could then be used to calculate the sound pressure level (SPL) at the receiver node through the propagation equation from:

$$SPL = L_{Max} \times LOG\left(\frac{distance}{recorded\_distance}\right)^2 - 11 \quad (2)$$

AEDT has the additional functionality of being able to perform a calculation of noise propagation with consideration of topography. This feature is known as line-of-sight blockage and when applied the computation time dramatically increases (Zubrow, Hwang et al. 2017). The next stage of the AEDT verification involved assessing maximum noise levels under the same conditions: with and without line-of-sight-blockage enabled in AEDT. 21 receptors were established in the Tasman Valley, and arranged in a transecting line, perpendicular to the helicopter flight path. The various receptors that calculated maximum noise levels under conditions of line-of-sight-blockage were then directly compared to the calculation without line-of-sight-blockage enabled.

The next model verification process entailed focussing on many helicopter operations, and the result this has on tranquillity levels. Franz Josef Valley was chosen as the subset focus area for its intensity of flight frequency. Instead of maximum levels, time above designated threshold levels were calculated to evaluate the effects of flight frequencies. Using the TRAPT equation, tranquillity ratings were established from the predicted noise levels, and could therefore be spatially represented. The effects of line-of-sight-blockage on tranquillity levels could therefore be efficiently compared.

3.2.4 AEDT Modelling and Tranquillity Prediction

AEDT was setup to perform a calculation of both parks- as they are situated side by side and share a large portion of boundary. 23 types of operations, representing 423 flights from a Eurocopter AS350 Écureuil during a standard operational day were imported using the methodology described in appendix G. Receptor nodes were evenly distributed in a 100 x 100 meter grid pattern.

Through the use of the recalibrated TRAPT equation (section 3.1.8), tranquillity levels representing the perspective of the general New Zealand population could be plotted as contours in maps of the two national parks that are the focus of this investigation. Following the recommendations laid out by Watts and Pheasant (2015), tranquillity levels are considered to be excellent between 8 and 10 on the TR scale, which for a national park environment; tranquillity of this level should be upheld. TRAPT was then used to determine the exact time below L_{Aeq} when TR ≥ 8. An AEDT calculation was performed to determine the time that receptor nodes measure noise levels to be below the L_{Aeq} threshold representing excellent tranquillity.

3.3 Visualisation of Results

3.3.1 Spatial Data

The output tranquillity contours were exported from AEDT representing the length of time that the L_{Aeq} was below the value when TR = 8, in increments of two hour periods.

Flight paths used as part of the AEDT calculations was also exported as a layer of polylines, and utilised in ArcMap to indicate where noise is expected to be highest and resultant rating of tranquillity is expected to be lowest.

Additional spatial information including the boundary for both national parks, helicopter landing sites (outside of the park), and key landmarks such as lakes and mountain ranges were used for labelling purposes, in order to improve spatial awareness.

3.3.2 Visualisation Practices

As the focus of this investigation is entirely on two national parks, any noise calculations outside the park boundary were cropped out of the final maps. Conventional mapping practices were applied to present the relatively unfamiliar concept of tranquillity to a mass audience. Examples include:

- Colour
- Transparency
- Labelling

3.3.3 Static Map

ArcMap is optimised for producing maps in their simplest form: two-dimensional and static. The output tranquillity maps from this stage were designed to be used as report figures and keynote presentations.

3.3.4 Interactive Web Map

The next evolutionary process of tranquillity maps was to enable audience interaction to improve understanding of the state of tranquillity in New Zealand national parks. ArcGISonline (My Map) was used as a platform to present tranquillity maps as well as able interactivity through activating layers providing the tools to navigate, zoom, and change aspect view angle of the tranquillity in the national park area.

4. Results

4.1 Field Measurements

Table 4.1: Measurements in Aoraki/Mt Cook National Park

Location	File	L_{Aeq} (dB)	L_{Amax} (dB)	L_{Amin} (dB)	Length (min. sec)	Description
site A	**M02**	34.0	48.4	31.9	2.02	Natural ambient noise. Small waves breaking on Tasman Lake shore
	M03	56.6	67.5	34.0	2.34	Predominant helicopter noise under the valley ridgeline
	M04	31.4	40.2	29.5	1.02	Natural ambient noise. Small waves breaking on Tasman Lake shore
	M05	40.5	54.5	31.8	4.33	Natural ambient noise with an approaching and passing helicopter
	M06	56.8	70.7	33.3	3.29	Natural ambient noise with an approaching and passing helicopter
Site B	**M07**	64.2	78.7	37.3	1.18	Fixed-wing flyby under the valley ridgeline
	M08	58.2	65.5	40.6	1.17	Helicopter flyby under the valley
	M10	78.1	89.8	37.2	2.50	A close approach and nearby hovering of a park management helicopter
Site C	**M12**	33.7	49.0	30.8	2.26	Natural setting with a few birds
Site D	**M14**	47.2	57.7	33.7	3.49	Natural ambient noise from cicada and occasional birdsong, with various fixed-wing and helicopters aircraft above the valley ridgeline, with
	M15	31.2	42.8	27.4	1.28	Natural ambient noise from cicada and occasional birdsong

Table 4.1 presents the results of eleven measurements at four locations, each a combination of aircraft and background noise. File M15, taken from site D, exhibited the lowest L_{Amin} level of 27.4dB. This location was the furthest away from moving water such as waves and waterfalls, and the wind speed was low. The highest noise level was at site B (M10) with a L_{Amax} of 89.8dB. The measurement was of a hovering

helicopter, approximately 50 metres from the SLM. This measurement was omitted and not included, as the helicopter is a misrepresentation of typical daily activity: the helicopter was being used for equipment movement which is not directly related to tourism operations.

Of the eleven measurements and recordings (not including calibration files recorded at each location) that were collected in Aoraki/Mt Cook National Park, five remaining recordings were deemed acceptable for further processing. With careful consideration, ten truncated files lasting 10 seconds were made from these remaining five recordings, used as below.

Table 4.2: Refined Audio Stimuli used in Tranquillity Assessment

Location	Source File	Truncated File	L_{Aeq} (dB)	Description
Site D	M09	TT10	29.0	Ambient cicada noise
site A	M03	TT4	32.9	Ambient waves breaking
Site A	M04	TT6	37.4	Helicopter at a very far distance
Site A	M04	TT5	38.0	Helicopter at a very far distance
Site A	M02	TT3	40.6	Ambient wind together with distant helicopter
Site D	M08	TT8	43.5	Cicada noise together with helicopter
Site A	M04	TT7	46.5	Helicopter noise
Site D	M09	TT9	47.6	Predominant helicopter noise with background cicada
site A	M02	TT1	51.3	Helicopter at closest point of passing
Site A	M02	TT2	55.3	Helicopter at closest point of passing

Table 4.2 shows the L_{Aeq} levels of ten truncated files and the source recordings that they originated from. The refined spread of the L_{Aeq} levels of the truncated file is 26.3dB, which reflects the range to be expected on the ground in the national park environment. Truncated files listed above were carefully selected, with the 10-second files not containing any distinguishable change (i.e. for aircraft an identifiable approach or leaving, instead a constant, uninterrupted sound). Measurements from sites B and C were omitted due to reasons of an unsatisfactory representation of anthropogenic noise, extensive contamination of background noise levels from footprints, voices, and other form of interference from people. These truncated files

are key to forming a common tranquillity rating and prediction for various levels, so the difference in L_{Aeq} needs to be around 3dB greater in order for participants to distinguish the audio files from one another.

4.2 Sample Population Demographics

Table 4.3: Demographic Distribution of Sample Population

AGE	18 - 25	26 - 40	41 - 60	over 61
2013 NZ Census	14.0%	25.0%	36.0%	25.0%
Sample Population	14.3%	25.7%	34.3%	25.7%
GENDER	**male**	**female**		
2013 NZ Census	49.0%	51.0%		
Sample Population	48.6%	51.4%		

The sample population consisted of 35 subjects, who were individually selected for the overall sample group. The sample group was a reasonable representation of the overall general New Zealand population. Table 4.3 shows the breakdown of demographics of the sample group compared with the census group. Alongside gender categories, four age were established. In this case, the largest deviation between the census population and the sample population was an underrepresentation of 1.71% for the group size of 41-60 year olds. The gender distribution of the sample group and the census population was representative, with 17 males and 18 females making up the sample group. All participants were required to be New Zealand citizens, and represented a range of age groups and an almost exact reflection of gender, based on the latest Census information (2013). New Zealand citizens, rather than national park visitors were required because the Conservation Act (1987) is concerned with conservation of national parks for the benefit use and enjoyment of the New Zealand public.

4.3 Tranquillity Calibration for the New Zealand National Parks

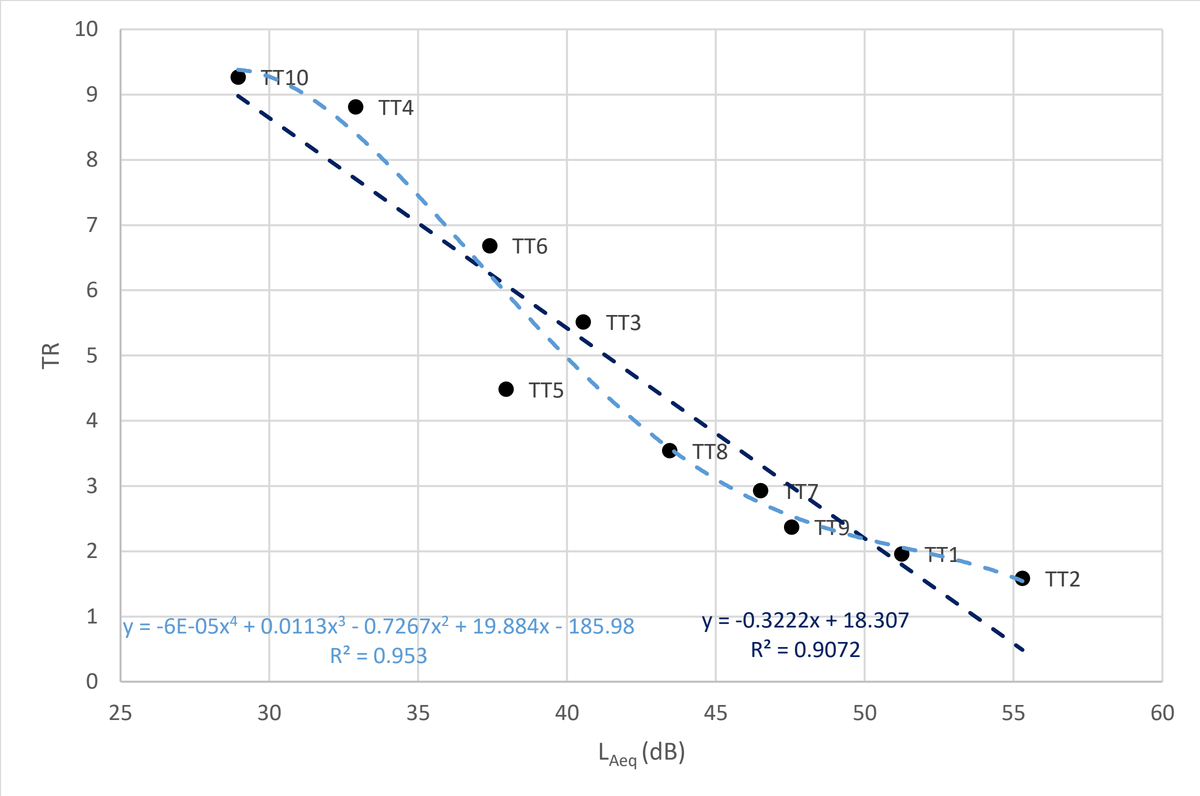

Figure 4.1: Tranquillity Ratings for National Parks

The initial results immediately following the tranquillity test of the entire population sample group of 35 can be observed in figure 4.1, where the overall average tranquillity of the ten stimuli as rated in the test by the general New Zealand sample population can be compared to the L_{Aeq} levels of the stimuli. Test stimuli with higher levels of L_{Aeq} appear to return a lower average rating of tranquillity. It is shown however that there is an outlier to this trend: File TT5 is rated much lower than its neighbour TT6, despite having a higher L_{Aeq}. This can be a result of more factors than simply L_{Aeq} determining the outcome of tranquillity. For example, the acoustical character emitted by the noise source could further affect the state of tranquillity alongside L_{Aeq}.

An almost exact negative relationship between average ratings of tranquillity and L_{Aeq} levels can be explored through a linear as well as a quadratic, fourth-order polynomial line of best fit. The fourth-order polynomial best describes the immediate effect that L_{Aeq} levels have to tranquillity levels, however the linear equation demonstrates a better overview and can be better compared to previous studies. Therefore, using the linear equation, recalibration of TRAPT to accommodate the tranquillity perspective to the general New Zealand population can be shown as:

$$\text{TR} = 18.31 - 0.322L_{Aeq} \tag{3}$$

As described in section 2.2, TRAPT traditionally employs three parameters. However, in the context of a New Zealand national park environment, the parameter for percent of natural or contextual features (NCF), as well as moderating features (MF) were removed. The recalibrated equation (3) can be compared to the TRAPT equation from Watts and Pheasant (2015) in the following figure.

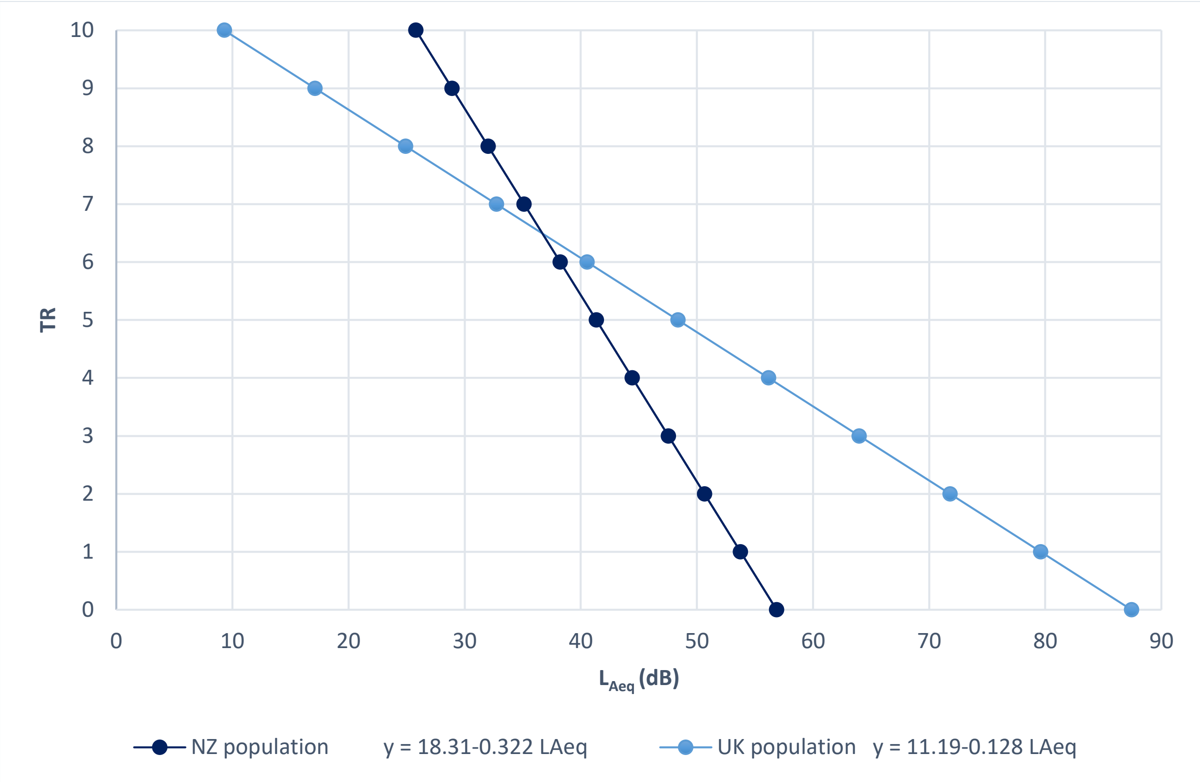

Figure 4.2: Tranquillity Ratings of New Zealand and United Kingdom

Figure 4.2 compares the relationships between the L_{Aeq} levels and the range of tranquillity according to the perspectives of the New Zealand national park environment as rated by the sample group in this investigation and that of the United Kingdom wilderness areas reported in previous work (Watts and Pheasant 2015). The results of both investigations share the same negative trend of lower L_{Aeq} levels determining higher levels of tranquillity, however in the New Zealand investigation tranquillity ratings exhibit a steeper trend with L_{Aeq} to that of the United Kingdom population. This can be partly explained through the presence of a range effect, where there is a tendency for the maximum and minimum ratings on the subjective scale to be given to the maximum and minimum levels irrespective of what those levels might be (Lawless, Horne et al. 2000). Consequently, the smaller range of noise levels in New Zealand compared to the United Kingdom investigation led to the steeper trend line of TR plotted against L_{Aeq}. However, the range of L_{Aeq} levels from the stimuli reflect for the most part the levels that are currently to be expected in the New Zealand national parks and so the recalibration is valid if used in context.

A further possible reason for variation from the United Kingdom setting is that the stimuli in this investigation was restricted to aircraft sounds while in the United Kingdom road traffic noise was included. If identical stimuli had been used for the NZ and United Kingdom population groups it is likely results would show no significant difference; this was demonstrated in a recent investigation carried out in Hong Kong (Watts and Marafa 2017), where three groups (from Hong Kong, Mainland China and a diverse group from 16 different nations) were in general agreement in rating tranquillity for the different studied in the trial.

The findings of this investigation show, that under the newly calibrated TRAPT equation for the local conditions, for a TR rating of 8 or more an L_{Aeq} of ≤ 32dB is required (under conditions of 100% NCF in the field of view). This is a difference of 7dB when compared to the United Kingdom TRAPT equation where a lower level of ≤ 25dB is required to sustain a TR rating of 8 or above.

4.4 AEDT Model Verification

This section of the investigation was concerned with determining if AEDT was producing consistent simulation results. Initial work with AEDT was conducted on a subset area of Franz Josef Valley that compared calculations with line-of-site blockage and calculations without line-of-site blockage. The initial TRAPT equation (1) from the United Kingdom investigation was deployed, as the recalibration to the New Zealand setting was still in development. The effect that terrain has on tranquillity was observed; using the two calculation outputs, tranquillity maps were produced (Figure 4.3), with contours representing the entire TR scale from 0 – 10.

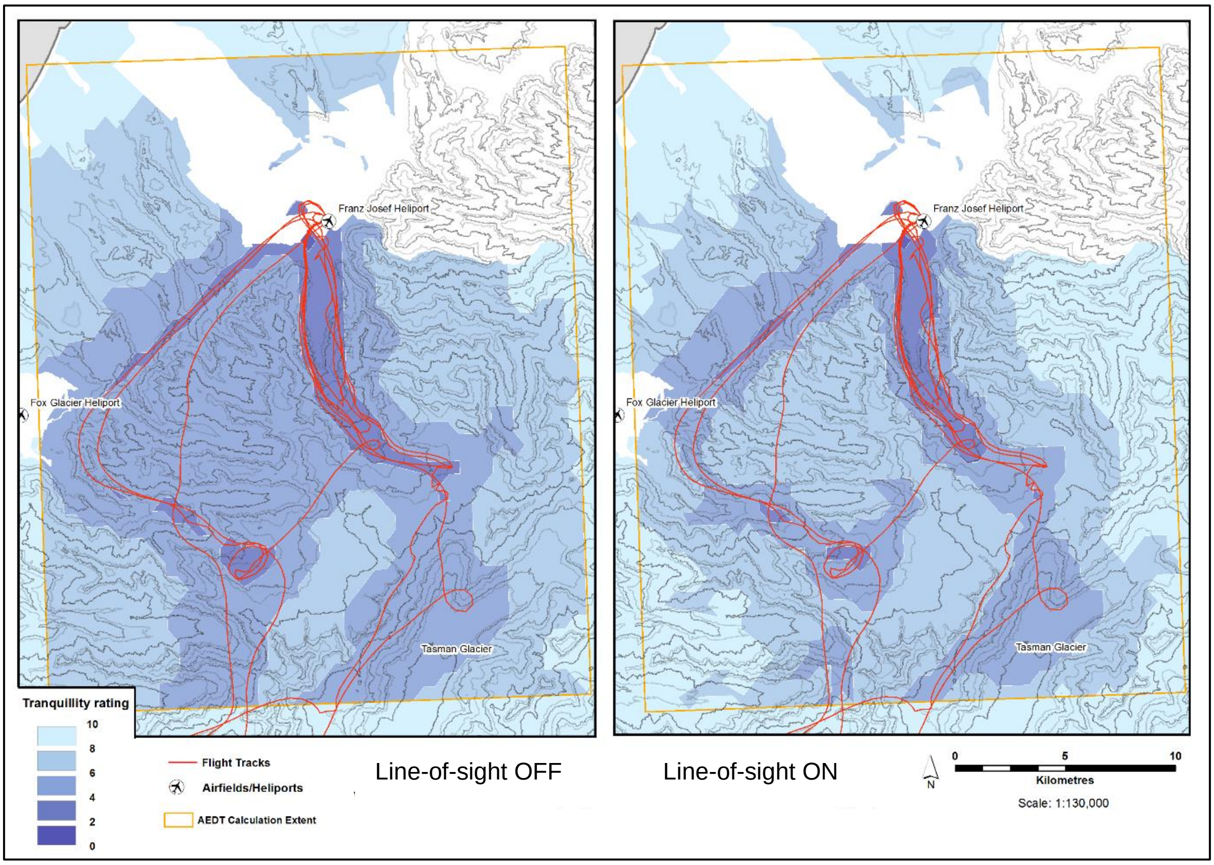

Figure 4.3: Effects of Line-of-Sight-Blockage on Tranquillity

Table 4.4: TR Contour Area Size Comparison

TR	Line-of-sight-blockage OFF (km^2)	Percent	Line-of-sight-blockage ON (km^2)	Percent
8 to 10	582	100	582	100
6 to 8	552	94.8	426	73.2
4 to 6	289	52.3	156	36.7
2 to 4	33	11.6	22	14.1
0 to 2	0.3	1.0	0.3	1.2
Area is calculated inside the orange bounding box (figure 4.3)				

The New Zealand high country, particularly the spine of the Southern Alps, is known to have a large variation in topography, with many tall ridges and valleys in a relatively small space. Assessing noise propagation with consideration of line-of-sight-blockage is indispensable for the environment investigated in this research. Comparing the maps in figure 4.3, a considerable difference in tranquillity predictions in the parks is apparent. The calculation without line-of-sight-blockage overestimates 'higher' prediction ratings of tranquillity (between six and ten) and underestimates low tranquillity ratings (under six). For example, the contour depicting tranquillity levels with obscuration analysis disabled from six to eight is calculated to be 552km² of the subset focus area (limited to the orange bounding box), but under conditions of obscuration is reduced to 426km² (Table 4.4). The contour depicting tranquillity levels from two to four reveals an opposite effect, where the measured area falls from 33km² for line-of-sight-blockage turned off to 22km² for the activated line-of-sight-blockage calculation. This exercise focussed on a subsection of Tai Tōponui Westland and with a reduced number of flights used in the calculation, tranquillity contours are likely to reveal a significantly different spatial distribution once the model is performed in its entirely encompassing both national parks and many more flights.

4.5 Tranquillity Maps

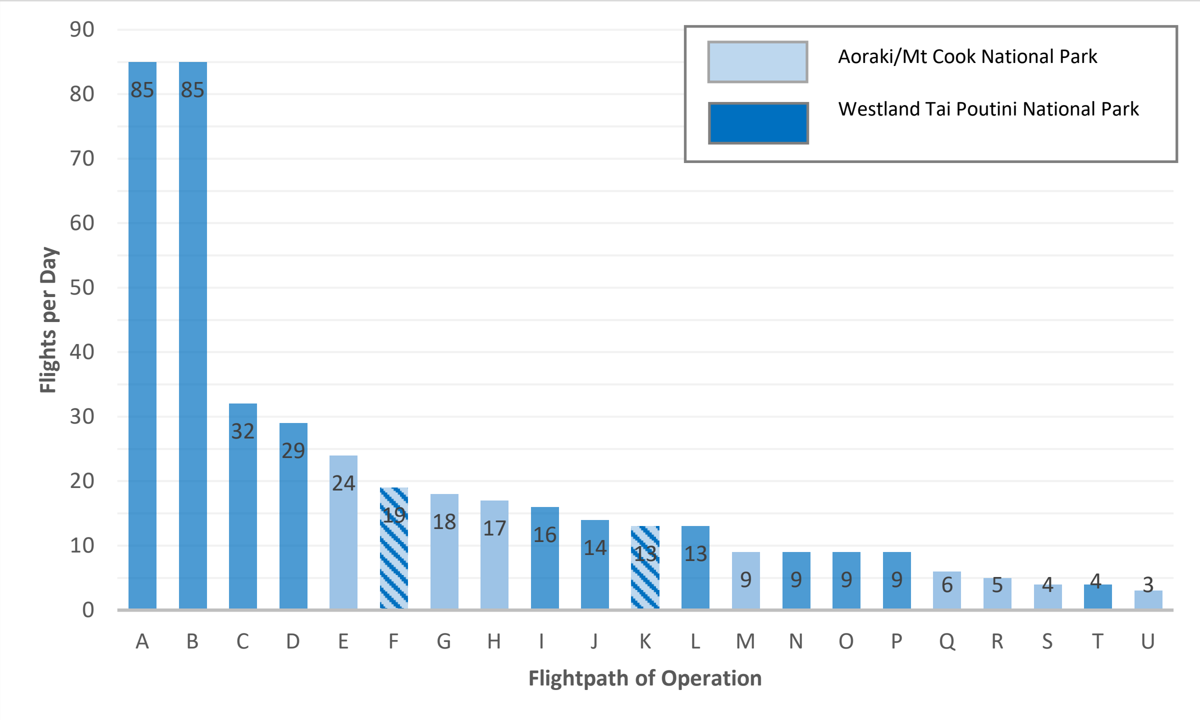

Figure 4.4: Number of Daily Operations

Figure 4.4 illustrates the expected daily operations in Aoraki/Mt Cook and Westland Tai Poutini national parks. The more operations that occur in one area (for example those that follow the same flightpath), an expected greater impact is likely to occur on the tranquillity of the place. It is shown that while there is an even spread of helicopter related activities between both parks, operations in Westland Tai Poutini

National Park exceeds the number of operations in neighbouring Aoraki/Mt Cook with significantly more flights occurring on a daily basis. Glacier tourism is known to be the cause of this phenomena, with about 85 operations occurring in the Fox and Franz Josef areas on a daily basis. The operation representing K is in fact a light fixed-wing aircraft, but was calculated as a Eurocopter AS350 Écureuil, however the GPS flight record was translated to work as a helicopter track as the fixed-wing template was not functional at the time. As 13 flights occur on a daily basis, as well as the fact that the flightpath traverses some remote spaces of the national parks, operation K was included as part of the calculation.

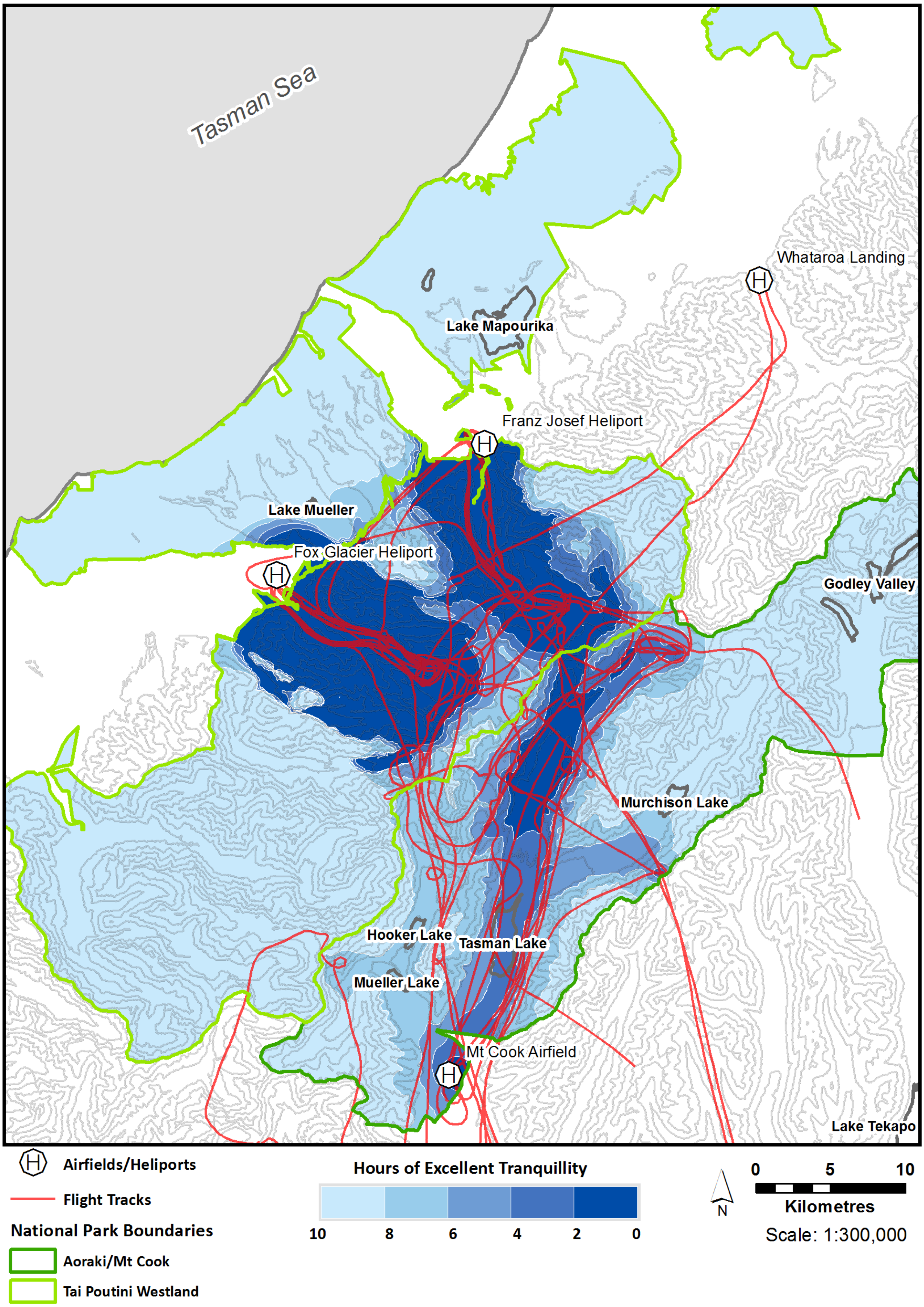

Figure 4.5: Static Tranquillity Map | Hours of Excellent Tranquillity (TR ≥ 8)

Figure 4.5 presents the spatial distribution of tranquillity. The map was produced with contours in distinctly identifiable colours spanning over the entirety of the park. Helicopter flight tracks were also presented in the foreground, and all other background features serving as secondary information to acquaint map readers with the area.

For this final iteration of map, the line-of-sight-blockage feature was not included as part of the calculation as the size of the investigation area was too large to be processed with current computing capabilities. This means tranquillity depicted in figure 4.5 would likely be higher beyond valley side ridges due to direct-path blockage given the trend shown from the model verification outcome from figure 4.3. This is not considered a setback to the investigation, as the aim was to provide a transparent proof of concept.

Some broad deductions can be made from the map, which shows that, for the most part, any form of helicopter activity in a space will result in a reduced number of hours of excellent tranquillity. Considering the amount of area that both parks encapsulate, there seems to be a significant imbalance of distribution of amount of hours areas are likely to be tranquil for. Approximately half of the park exhibits excellent levels of tranquillity for over eight hours**.** Two areas are of most concern: Fox and Franz Josef glaciers in Westland Tai Poutini National Park, where most of the flights of frequent operation are clustered. The third area where excellent tranquillity levels are compromised is the upper section of the Tasman Valley in Aoraki/Mt Cook National Park, which is again likely to be a result of glacier tourism.

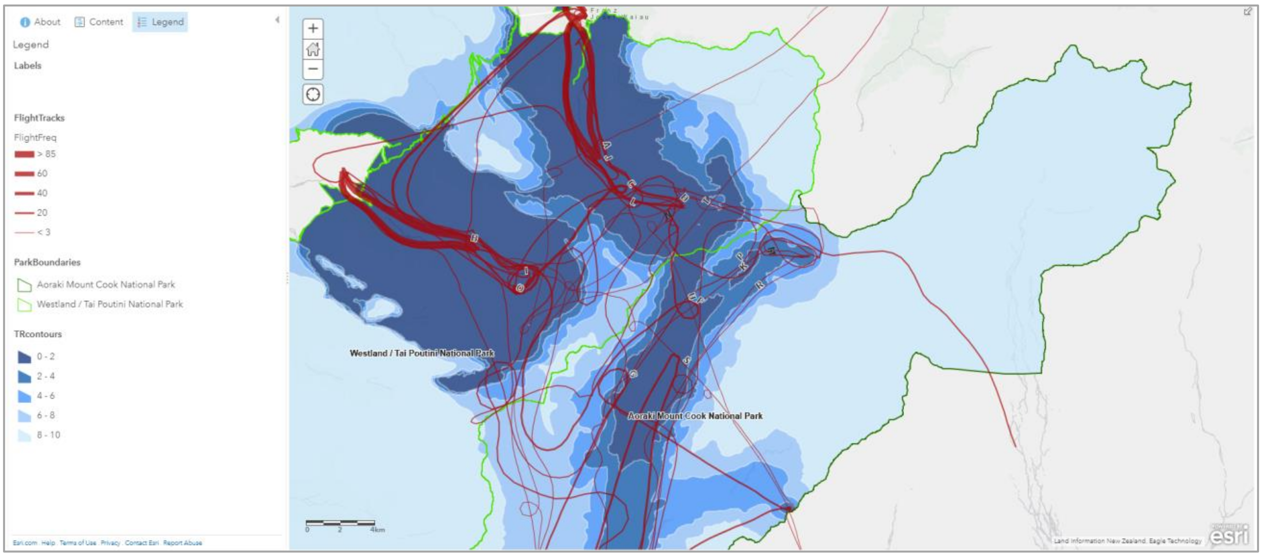

Figure 4.6: Interactive Web Map | Hours of Excellent Tranquillity (TR ≥ 8)

Figure 4.6 illustrates the same tranquillity map, but on a web-based platform. As the map is no longer on a fixed scale, readers are given the opportunity to interact with the map by panning and zooming to various sections. As a result, labelling and overlapping of spatial information was not so accurately distributed. One such example is the flight tracks were presented in varying thicknesses, depending on how many daily flights they accommodate. The benefits of this application is thicker lines gravitate the readers' attention to areas that exhibit reduced levels of tranquillity. If chosen to be explored in more detail, the reader can disperse the overlapping flight paths by zooming into the map. The tranquillity web map has further taken advantage of a dynamic platform through the use of labelling geographic features of importance at different scales. The web map can be accessed using the following link: https://arcg.is/04infP

5. Discussion

5.1 Investigation

It was demonstrated to be worthwhile to determine the subjective noise prediction of the general New Zealand population rather than use the assessment of the United Kingdom population. The levels of tranquillity were assessed based on the predominant noise source currently experienced in New Zealand national parks (helicopters). The calculation of noise levels was based on common flight operations of a Eurocopter AS350 Écureuil. This investigation developed a transparent methodology that can be implemented in other national parks.

Field Data Collection

To obtain an accurate reflection of the acoustical characteristics of the dynamic soundscape, measurements and recordings of helicopter noise were taken with the intention of incorporating the entirety of a passing helicopter- from distant approach to distant departure, and ambient background noise measurements were made when only ambient sound was present. The decision to measure and record data at four different sites was made in order to have fair representations of the natural acoustic environment and anthropogenic noise likely to be experienced in the national park. Unfortunately measurements and recordings at two of the four locations were omitted from further processing because of the inadequate quality of the recordings. The remaining two sites, however, provided enough data with a satisfactory range for the investigation to progress.

Background Noise

An unanticipated result was for the national park environment Aoraki/Mount Cook National Park was the level of background noise was higher than expected. At site D, L_{Amin} was measured to be 27.4dB, due to ambient noise being produced from insects, waterfalls, breaking waves, birdsong, wind, and rustling vegetation, background. The relatively high background L_{Aeq} levels influenced the tranquillity testing and recalibration of TRAPT by condensing the range of L_{Aeq} levels compared to those encountered in the United Kingdom investigation (Watts and Pheasant, 2015).

Population Sample Group

TRAPT has been applied to various situations since its initial deployment- from urban areas to protected wilderness areas, with its focus on the subjective response of the United Kingdom population. This investigation had the TRAPT equation recalibrated to represent TR trends for the local conditions in New Zealand national parks. The sample population of 35 subjects was considered to be large enough in size in order be able to produce an average tranquillity rating to represent the wider population of that group. The 35 subjects gave a reasonable representation of the overall general New Zealand population by comparing age and gender categories as a percentage with the 2013 Census. The work could be extended to determine the specific response of the Māori population as certain cultural values that are shared amongst Māori may have an influence on the tranquillity of a place from their perspective.

Sound Pressure Level as the Primary Predictor

The sound pressure level, measured in $L_{Aeq,}$ was applied as the primary predictor for tranquillity through TRAPT. As was the case for Watts and Pheasant (2015), there was a clear negative correlation between L_{Aeq} and resultant TR. As previously noted, there was one outlying noise file that, to the general New Zealand population, on average was given a low tranquillity rating despite having a relatively low noise level. Although L_{Aeq} was a significant predictor, there are other possible aspects to consider that have an effect on the TR that could explain the sound file outlier, for example the sound character, which can be assessed though the use of psychoacoustic parameters. Loudness, roughness, sharpness, and pitch are for example, characteristics of sounds that influence a listener's reaction it (Howard and Angus 2009). The characters of the sounds contained in the noise files can have an influence on the rating of tranquillity and as such, could be the case for the noise file outlier.

TRAPT

By analysis of the direct effects that L_{Aeq} has on tranquillity levels, a relationship was observed through the application of linear and forth-order polynomial trend lines of best fit and logistic function. Previous iterations of the TRAPT equation has always been formulated using a linear relationship, and this investigation was no different. It was however, thought that the additional analysis of a polynomial function could be beneficial to explore the relationship in more detail. It has been addressed that in participant-driven subjective studies such as this there can be a tendency for participants to not use the whole scale when rating the highest and lowest levels of the stimuli. While the linear trend line overlooks this phenomena, the polynomial function in particular compress the x-axis values (L_{Aeq}) at the extremes of the stimulus range resulting in an S shaped curve. In the end, the linear relationship was chosen to represent TR as it serves as a better tool to compare to previous tranquillity investigations focusing on the application of TRAPT.

Excellent Tranquillity

The recalibration of the TRAPT model indicates that compared to previous studies of the general United Kingdom population, there is a 7dB difference associated with levels of excellent tranquillity (TR = 8). This can be explained by the difference in the range of noise levels measured in Aoraki/Mt Cook national park when compared to the range from the United Kingdom investigation, which additionally included traffic noise sources (Watts and Pheasant 2015).

Noise Model Verification

A small-scale AEDT calculation of effect of the noise level for one passing helicopter on six receptors was performed (Section 3.2.3) For the hand calculation, the direct comparison of the two calculations proved to be difficult, as results differed between the same receptor nodes by up to 10dB(A). The difference was attributed to such factors as altitude, air temperature and pressure, humidity, and helicopter velocity, which are not included as part of the distance-noise ratio equation (2). It is expected that if these additional factors were to be assessed alongside the distance-ratio noise calculation, the results between the two approaches are more likely to have a similar outcome. A common flaw of noise calculation software share is the limited accuracy when compared to the real-world situation. However, AEDT has been demonstrated to give high quality simulations as it was initially designed for the United States military complex, and later evolved to accommodate civil operations.

Calculation of Noise in National Parks

Anthropogenic noise propagation was calculating using AEDT. This software was carefully chosen for the modelling of anthropogenic noise in New Zealand national parks as it has many advantages over other noise calculation software currently available. The ability to evaluate the effects of noise propagation in areas of variable terrain was of high importance. While a range of noise calculation software programs offer this capability, AEDT demonstrated the additional feature of factoring in line-of-sight-blockage into the noise calculation. The New Zealand national park environments can be unique settings with vast changes of terrain in relatively confined areas, noise propagation and tranquillity ratings are heavily dependent on the immediate terrain of these environments. In the model verification process, figure 4.3 demonstrates how line-of-sight-blockage can heavily influence the outcome of the model, the use of AEDT is therefore warranted. AEDT also has capability to model a range of fixed-wing aircraft types as well as helicopters, which can be used in future work.

Maps of Tranquillity

The tranquillity maps presented in section 4.5 were produced with consideration to best maximise the readers understanding. A series of developments entailed, particularly regarding the design style to ensure that the maps effectively illustrate tranquillity levels in national parks. For example, visual hierarchy was a factor that contributed to the choice of colours used. It was decided to use shades of blue to represent a variation of tranquillity levels, and a strong red in the foreground to symbolise flight paths. Transparency of the lines was then adjusted to 40%, to blend the flight lines with the rest of the maps contents. Lower down on the visual hierarchy of information, two different shades of green were used to represent each of the park boundaries; easy to differentiate from one another, yet simultaneously not detract viewers' attention from primary contents of the map. All other features displayed on the map such as water bodies and elevation contours serve as background information and only serve to help readers with spatial awareness.

The static map was set at a scale of 1:300,000, an extent that covers majority of the two parks, without compromising on detail of where helicopters operate and the effect this has on tranquillity. At this scale, only a select few features could be labelled, usually iconic features. On the contrary, for the design of the tranquillity web map, this was not a problem as readers could interact with the map, including changing the viewing extent. This function was particularly useful when applying labels to many more geographic features of interest.

Fitness for Purpose: Visualising Tranquillity

The outcome of this investigation was the production of tranquillity maps of Aoraki/Mt Cook and Westland Tai Poutini national parks that effectively illustrate current helicopter operations. This work can improve understanding of anthropogenic noise as an issue in pristine natural environments, and how it can be used as a park management tool to properly manage these settings for the betterment of New Zealanders. TRAPT was invested to take the subjective concept of tranquillity and process it in a meaningful way. To some extent, the same applies to GIS as a toolset: abstract ideas can be transformed into informative planning tools. While noise mapping has been common in investigations concerned with environmental noise, tranquillity in map form has been much less common. Furthermore, an investigation of this nature has not been performed in the New Zealand national park environment. Maps depicting levels of tranquillity based on the perspective of the general New Zealand national park environments could serve as a beneficial planning tool for future consideration of management of soundscapes in national parks.

5.2 Limitations

Tranquillity is Subjective

A limitation of this investigation is that tranquillity ratings are results of the subjective responses. Consequently, this means that any assessments made by participants during the test are open to interpretation, and may be influenced by the individuals' mood or state of mind.

In this investigation, the exposure of participants to the sound of helicopters may trigger a range of emotions that are not necessarily directly associated with tranquillity. Some participants may share a fascination with helicopters, while others may react to isolation in a national park (no helicopters in the setting) with fear, which in turn can influence the subjects' assessment of tranquillity.

While the listening booth was used to restrict outside noise interference, it was a simulated environment, it could not represent the actual national park environment. Some participants commented that it was difficult to imagine themselves to be present in a natural environment whilst seated inside the listening booth though efforts were made to provide context by providing a visual reminder of the environment the sounds were recorded in.

The order in which the ten listening stimuli are played would have an influence on participant assessments of tranquillity, as participants are likely to make direct comparisons between files played before and after each other. This effect was mitigated by randomising the sequence for each participant, and having a test comprising of not one but three repetitions; one to learn the range of sound levels and variation of noise source types, and the next two to form an average of the responses.

Sample Group Representation

It proved a challenge to establish a sample group representative of the general New Zealand population beyond basic demographics such as age and gender. The majority of participants were (to a large degree) closely associated with the University of Canterbury, either as staff members, workers, or students. It can be assumed therefore that the sample population group has a high level of education, with a background of thinking and reasoning in ways that may not represent the wider general New Zealand population. This also means that minority ethnic groups were not considered. All participants were local to Christchurch and not geographically representative of New Zealand as a whole. However, any form of subjective testing has its limitations, so will always be a challenge to represent a groups' opinion of a subject based on individual responses. Having the sample population group comprise of 35 participants has minimised the influence of rogue subjective response to the tranquillity tests. Consequently, the recalibrated TRAPT model provides useful insights into the responses to helicopter noise in national parks, and can be used for further investigations in the future.

Other Noise Sources

This investigation was focussed on anthropogenic noise pollution from helicopters, which cover the majority of operations in the parks. There are also a number of other notable sources of anthropogenic noise in other national parks in New Zealand such as fixed-wing aircraft, jetboats, snowmobiles, and other vehicles, which have not been factored into this investigations calculations. Using the example of this investigation, only one of the 22 operations given by the GPS measurements are representative of a fixed wing aircraft. The flight pattern was isolated in nature, flying over some very remote valleys in some places far from helicopter activity. In order to spatially display the entire state of tranquillity in the national parks, it was justified to incorporate the flight operation of the fixed-wing by treating it as a helicopter in the calculations. Despite the differences of noise from differing spectral signatures, it was considered more useful to plot a noise source unique to helicopters in order to represent a reasonable amount of tranquillity in these isolated areas. In future research of tranquillity mapping for New Zealand national parks, where other noise sources are also identified, the limitation of misrepresenting fixed wing activity will be resolved.

The current means of calculation of the noise effects of helicopter operations using AEDT can be extended to fixed-wing with more investment of time and resources. While both rather prominent sources of anthropogenic noise, the spectral signature considerably differs between the two, which, in theory, will also give unique subjectivity of tranquillity in response to the two noise types.

Static Display of Time

A particularly problematic aspect of the current anthropogenic noise issue is the duration of the noise exposure. For this reason, this investigation focussed on anthropogenic noise pollution from helicopters over the course of a 10-hour operational day. Flight tracks used in the calculation were obtained from real-world GPS measurements, however temporal information of helicopter positioning was removed in the process of grouping similar operational activities together. The maps therefore illustrate tranquillity levels over the day which was possible through setting each operation a given frequency of flights, but fails to examine the extent in closer temporal detail. In this current situation a possible quiet period in the day will be overlooked. It is suggested that time-space maps could offer a greater understanding by potentially modelling the real-time impact that a helicopter has on tranquillity levels.

Environmental Variables

As noted in 3.2.2, calculations in AEDT were performed assuming a standard atmosphere. Pressure and temperature have an effect on sound propagation, but in the area of investigation, spanning two national parks, these ambient conditions are not necessarily always uniform. The high country alpine environments ambient conditions found in Aoraki/Mt Cook National Park can differ from that of the coastal and temperate rainforest sections of Westland Tai Poutini National Park. Additionally, weather systems in New Zealand are known to fluctuate between the months of the year. Both atmospheric pressure and temperature have an effect on the propagation of sound. The area of investigation used in AEDT calculations spanned over 10 billion square metres and as time-above was the designated metric, it was impossible to segment into smaller sections (for example independent calculations for each park). Although it is assumed that helicopters are mostly in operation when weather is calm and visibility is fine, further work could be performed to properly include ambient conditions.

6. Conclusions and Recommendations

The overall aim of this investigation was to present an approach for mapping tranquillity of New Zealand national parks based on the subjective response of the general New Zealand population. The equation for predicting tranquillity developed for the United Kingdom population (TRAPT) required recalibration to represent the general New Zealand population response. The outcome of assessing the general New Zealand population in this investigation indicated that to obtain a tranquillity rating of 8 or higher, the noise levels in the national park environment should not exceed 32dBA.

A time-above threshold calculation was performed using AEDT. This was based on the noise emitted by aircraft, which was used to plot the spatial distribution of TR ≥ 8 as static and interactive, online tranquillity maps. The unique terrain of the New Zealand national park environment calls for the additional need for line-of-sight-blockage to be implemented as part of a noise calculation, however the final iteration of maps did not consider this variable due to limitations with computer processing power.

The majority of anthropogenic noise in Aoraki/Mt Cook and Westland Tai Poutini national parks originates from helicopter operations, subsequently this investigation only considered noise from helicopters. There are other sources of noise that are likely to have an impact on tranquillity such as fixed wing-aircraft, which could be considered in future work. The findings from this work can be applied to assess the states of tranquillity in other national parks and conservation areas.

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Appendix A: Human Ethics Application Approval

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson
Telephone: +64 03 369 4588, Extn 94588 Email:
human-ethics@canterbury.ac.nz

Ref: HEC 2016/46/LR Amendment 1

15 August 2017

John Pearse
College of Engineering
UNIVERSITY OF CANTERBURY

Dear John

Thank you for your request for an amendment to your research proposal "The Effects of Helicopter Noise on Perceived Tranquility in New Zealand National Parks" as outlined in your email dated 10th August 2017.

I am pleased to advise that this request has been considered and approved by the Human

Ethics Committee. Yours sincerely

pp. R. Robinson

Associate Professor Jane Maidment
Chair, Human Ethics Committee

Appendix B: Participant Flyer

Experience a New Zealand National Park!

Geographic Information Systems Thesis research participants needed!

- Do you love our natural environment? Do you like receiving coffee vouchers? Are you a New Zealand citizen? Then this is the study for you!
- The Department of Conservation has identified helicopter noise as a problem in New Zealand national parks. But how much is too much?
- This study aims to determine acceptable levels of helicopter noise, and how they affect national park visitors.
- All that is required from you is 20 minutes of your time, while you are presented with imagery and sound clips from a New Zealand National Park, and you tell us how tranquil they make you feel! Easy as!
- If you are interested, please contact one of the following:

UC UNIVERSITY OF CANTERBURY

Johann Kissick:
johann.kissick@pg.canterbury.ac.nz
(+64) 278100565

John Pearse:
john.pearse@canterbury.ac.nz
(+64) (3) 3692423

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Appendix C: Online Participant Signup/ Information Page

The Effects of Helicopter Noise on Perceived Tranquillity in New Zealand National Parks

My name is Johann Kissick and I am a Masters of GIS (Geographic Information Systems) student at the University of Canterbury. My thesis is concerned with the impact of helicopter noise on visitor experiences in New Zealand National Parks. This research study aims to assess whether an established noise measurement and tranquillity prediction tool known as the TRAPT model, can be applied in this situation. Tranquillity can be defined as 'calm and peaceful and without noise, violence, worry, etc.'

If you choose to take part in this study, your involvement in this project will require an investment of about 20 minutes of your time. Testing will involve listening to a set of sound clips of helicopter noise at various volumes, and stating how tranquil you find the noise. The test will take place at University of Canterbury, Christchurch. Participation is voluntary and you have the right to withdraw at any stage without penalty.

The written documents that will be produced are expected to include a thesis and a paper in an academic journal. The project is being carried out as a requirement for the Masters of GIS degree by Johann Kissick under the supervision of Dr. John Pearse, who can be contacted at john.pearse@canterbury.ac.nz . He will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Human Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

Johann Kissick.

First Name

Last Name

Email Address

Contact Number

Gender

Age Group

Ethnicity (select any that you identify as)

- [ ] NZ European
- [ ] Maori
- [ ] Pacifica
- [ ] Asian
- [ ] Middle Eastern/Latin American/African
- [ ] Other ethnicity

Subscribe to list

Appendix D: Participant Information Sheet

Research Participant Information Sheet

Phone: 027 8100 565
Email: johann.kissick@pg.canterbury.ac.nz

The Effects of Helicopter Noise on Perceived Tranquillity in New Zealand National Parks

Information Sheet for research participants.

My name is Johann Kissick and I am a Masters of GIS (Geographic Information Systems) student at the University of Canterbury. My thesis is concerned with the impact of anthropogenic noise on visitor experiences in New Zealand National Parks. During this study, I will be the primary researcher and reporter.

The Department of Conservation has identified man-made noise – such as helicopter noise – as an environmental issue in New Zealand National Parks, affecting visitors and making their experiences less enjoyable. To address this, the Department of Conservation would like to establish a method of measuring noise levels, and predicting how these noise levels affect visitors, and to what extent. This research study aims to assess whether an established noise measurement and tranquillity prediction tool known as the TRAPT model, can be applied in this situation.

Participants are requested to assess tranquillity for two national parks: Mt Cook and Whanganui. Your involvement to assess **two national parks** will require an investment of about 20 minutes of your time. During this time, you will be seated in a test environment with a television screen showing a picture of a typical New Zealand National Park. Testing will involve listening to a **set of 10 ten-second sound clips** of anthropogenic noise at various volumes, and stating how tranquil you find the noise. This will be **repeated 3 times**.

Participation is voluntary and you have the right to withdraw at any stage without penalty.
You may ask for your raw data to be returned to you or destroyed at any point.
If you withdraw, I will remove information relating to you.
However, once analysis of raw data starts on the 15th of June 2018, it will become increasingly difficult to remove the influence of your data on the results.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public without your prior consent. To ensure anonymity and confidentiality, any information collected that contains identifiable information (such as consent forms) will be stored separately from results and data, and they will be stored in a secure lockable facility. Data will also be stored on a password protected computer that will be accessible only to those involved in this research. Data collected for this study may be used in subsequent research; however, confidentiality and anonymity will be preserved for any use of data.

Data will be stored for 5 years following the completion of the research, at which time all data and information will destroyed. The written documents that will be produced are expected to include a thesis and a paper in an academic journal. A thesis is a public document and will be available through the UC Library; academic papers vary in their availability, based on the publication.
Please indicate to the researcher on the consent form if you would like to receive a copy of the summary of results of the project.

The project is being carried out as a requirement for the Masters of GIS degree by Johann Kissick under the supervision of Dr. John Pearse, who can be contacted at john.pearse@canterbury.ac.nz . He will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Human Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, you are asked to complete the consent form and return it to Johann Kissick at the pre-arranged meeting [details can be confirmed via email: johann.kissick@pg.canterbury.ac.nz].

Johann Kissick.

Appendix E: Participant Consent Form

UNIVERSITY OF CANTERBURY

Consent Form

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The Effects of Helicopter Noise on Perceived Tranquillity in New Zealand National Parks

Consent Form for Research participants

I declare and fully understand the following:

□ I have been given a full explanation of this project and have had the opportunity to ask questions.
□ I understand what is required of me if I agree to take part in the research.
□ I consent to taking part in both national park tranquillity assessments.
□ I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.
□ I understand that any information or opinions I provide will be kept confidential to the researcher, Johann Kissick, and that any published or reported results will not identify the participants.
□ I understand that a thesis is a public document and will be available through the UC Library.
□ I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after five years.
□ I understand that data collected from this study may be used in subsequent research.
□ I understand the risks associated with taking part and how they will be managed.
□ I understand that I am able to receive a report on the findings of the study by contacting the researcher at the conclusion of the project.
□ I understand that I can contact the researcher, Johann Kissick [johann.kissick@pg.canterbury.ac.nz; 027 8100 565] or supervisor, John Pearse [john.pearse@cantercury.ac.nz; (+64) (3) 3692423 ext 92423] for further information.
□ If I have any complaints, I can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)
□ I would like a summary of the results of the project.
□ By signing below, I agree to participate in this research project.

Name:

Signed:

Date:

Email address (for report of findings, if applicable):

Appendix F: Participant Response Sheet

1

Tranquillity:

1) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
not at all tranquil very tranquil

2) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10

3) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10

4) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10

5) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10

6) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10

7) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10

8) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10

9) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10

10) 0-----1-----2-----3-----4-----5-----6-----7-----8-----9-----10
not at all tranquil very tranquil

Appendix G: AEDT Import Flight Data Protocol

G1. Introduction:

The following describes the necessary process to use custom GPS flight information in *AEDT*, as opposed to standard approach/departure tracks and official FAA prescribed, uniform, flight profiles.

AEDT segregates flight track and flight profile information, and only combines the two to form a flight path just before the noise metric calculation phase: in the operation of creating an annualisation. This may come across as peculiar, however the reasoning behind this is *AEDT* is an environmental noise calculation tool specifically for flight modelling and even more specifically for near-airport operations. The flight track is considered part of the airport information, while flight profile belongs to details of the aircraft.

G1.1 Tracks

Tracks are far less complex than the latter type- simply consisting of a series of nodes and their longitude and latitude coordinate reference. Essentially the tracks run along the ground either to or from an airport, and therefore is nested within the airport information.

G1.2 Profiles

A complete profile requires many more variables than for a track, the variables of which are stored in steps (just as tracks have nodes). Depending on the step type, it contains various information which can include altitude, speed, distance to the next step, and duration in a stationary hover or grounded position. The eventual calculation is based on the nature of the aircraft noise source (the engine type and directivity) as well as its position in the sky, therefore the profile is nested inside the aircraft information.

A profile takes on one of four types: approach, departure, taxi or overflight. Again, the software is designed for operations near airports, aircraft of which would always take one of the four forms. In a New Zealand national park scenario, operations are far more complex than a simple take-off or landing; in some cases operations extend beyond flying out of an airport to land on a glacier (where no airport is designated). For the above reasoning, overflight profile types offer the best application to model a national park scenario. Despite its name, overflight is a combination of approach, departure and taxi profiles, meaning it is possible to take off and land to and from an airport using an overflight profile. This work through document explains how to set up an overflight profile specifically.

G2. Designing an ASIF:

G2.1 ASIF fundamentals

When not using a standard FAA flight track and profile, it is required to be imported via ASIF (AEDT Standard Import File). This file is in an .xml format and can be visualised in a range of software; for this process, *Notepad* ++ is used. An ASIF can contain a full study or a partial import of one. A full study imports all relevant information to produce a noise metric calculation in one action, and does not require repetition. A partial import ASIF is designed to bring in additional information if necessary. In this exercise, a full study ASIF is described. Templates can be found in the following directory, and will be attached to this document.

W:\Acoustics\JOB FILES\A to H\DEBT of CONSERVATION\JOHANN KISSICK WORK\Templates

G2.2 Aircraft and flight profile

AEDT contains a range of aircraft, both fixed wing and rotary, in the equipment library. Each aircraft contains very specific details required to yield efficient noise dispersion and fuel emission calculations. Airframe, engine, and rotor dimension details are a few examples of this, alongside the aircraft profile information. To modify the profile, it needs to be exported from *AEDT* in .xml format. The airport .xml file is much similar and does not require as much specific information, so an airport template .xml was sourced from the aforementioned directory and modified accordingly.

G2.3 Flight profile variables

The raw GPS data is in vector point format, in metric units of measurement. Using a conjunction of *Microsoft Excel* and *ArcGIS* functionality, the following variables can be calculated: speed, distance between points and altitude above starting airport. In addition, all units of distance are translated to imperial feet and speed to knots. For each step in the aircraft profile, a further variable is required that corresponds with the current action of the step, which takes the form of a letter seen below right.

Table 1: Step codes for an AEDT aircraft profile

Step Type	Description	State	Parameters
A	Approach at constant speed	Move	Dist Alt
D	Depart at constant speed	Move	Dist Alt
X	Level flyover at constant speed	Move	Dist
G	Ground idle	Static	Dur
H	Flight idle	Static	Dur
I	Hover in ground effect	Static	Dur
J	Hover out of ground effect	Static	Dur
V	Vertical ascent in ground effect	Static	Dur Alt
W	Vertical ascent out of ground effect	Static	Dur Alt
Y	Vertical descent in ground effect	Static	Dur Alt
Z	Vertical descent out of ground effect	Static	Dur Alt
B	Approach with horizontal deceleration	Move	Dist Spd
C	Approach with descending deceleration	Move	Dist Alt Spd
E	Depart with horizontal acceleration	Move	Dist Spd
F	Depart with climbing acceleration	Move	Dist Alt Spd
T	Taxi at constant speed	Move	Spd
S	Start altitude at constant speed	--	Alt spd

Each step identifier is defined based on the relationship it shares with the previous step in the sequence. For example, if there is an increase in speed or altitude: it is given the step type corresponding accelerating ascent. Furthermore, the step type of the direct neighbours need to connect by an arrow seen in the diagram below. This means for an aircraft to go from departing constant speed to approaching vertical, a level fly step is required in between. Although it is possible to give the step type variable through automation in script format, it is advised to do so manually or at as a minimum requirement oversee the output as scripts can easily be error-prone if not written correctly and a single wrong step type can result in an overall *AEDT* error.

G2.4 Translating table rows to ASIF.xml

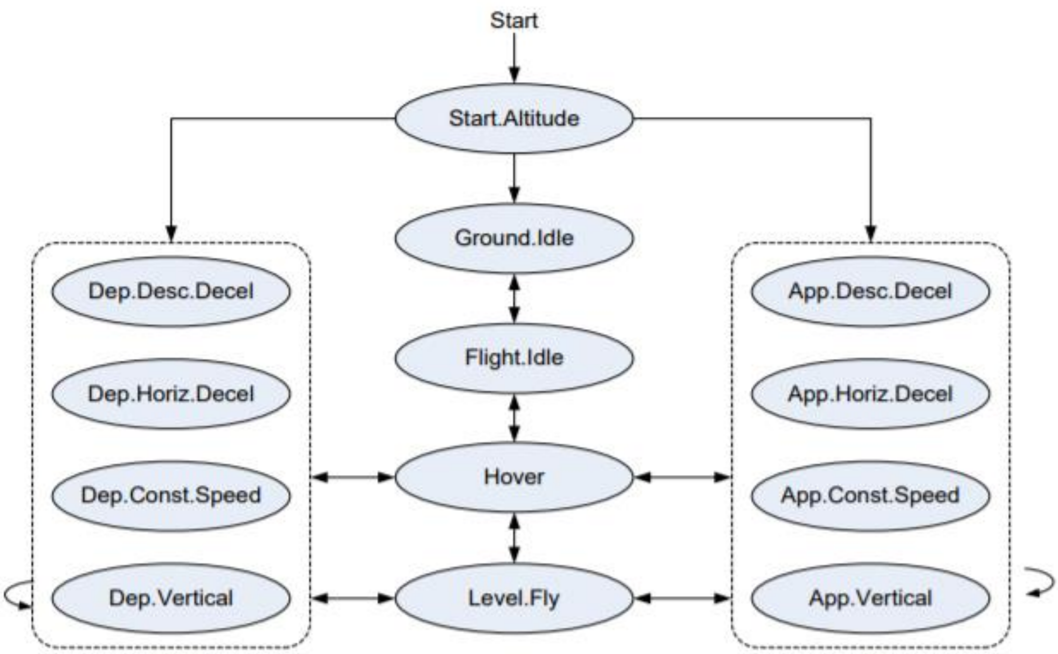

Figure 1: Relationship between step types

As previously explained, aircraft profile and airport track are segregated from each other. However, they are able to be contained in the same full study ASIF. The exported *AEDT* aircraft with FAA-prescribed flight profiles can be copied into the full study template. Once transferred over, the unique identifiers for the following categories need to be changed to an identifier different to the original exported file:

- NoiseID
- Airframe model
- EngineCode
- EngineModCode
- AnpHelicopterID

The changing of the unique identifiers above is necessary as *AEDT* does not accept double up identifiers for any sections of the airport profile. If this action is dismissed, the ASIF will fail to import.

Altova Mapforce is used in conjunction with *Microsoft Excel* to convert rows of data in an attribute spreadsheet into an .xml file under sections of helicopter profiles and airport tracks.

The node indentations for track and step indentations in .xml script format from *Altova Mapforce* is then added copied into the template .xml. Ensure that the standard FAA-prescribed profile remains if modelling helicopters, and simply add the new custom profiles on the following line. It is recommended to do a manual check of the .xml code, to resolve any errors as this is the last opportunity before *AEDT* import.

G3. Preparing a calculation in AEDT

The listed sequence of actions are to take place to complete pre-processing and perform a metric calculation:

- Import ASIF.xml
- Close and restart AEDT (and check equipment list for newly imported aircraft)
- In operation tab, create new aircraft in overflight mode using approach profile
- Close AEDT and open Microsoft SQL server management studio
- Open tables for both operations and helicopter profiles to check on their contents (specifically profile ID)
- Launch SQL query to modify table contents
- Close SQL Management Studio and open AEDT
- Create Annualisation using modified operation
- Create Receptor/Receptor Grid and Metric Result

G3.1 Import ASIF.xml

The .xml file can now be imported into *AEDT* via the study ribbon. The contents of the .xml file includes all relevant information to establish a new study. The import feature can only be used once per study. If any more additional information (for example more flight profiles or airport tracks), the *ASIF.xml* needs to be formatted slightly differently to be able to be used via the partial import function, which can be performed many times over provided that all *ASIF.xml* identifiers are unique.

The import will be successful once all floating windows have disappeared. *AEDT* then needs to be refreshed with newly imported information by shutting down and restarting the program. In the equipment tab, the copied aircraft is listed at the bottom of the table, and in the airports tab the imported airport will be listed on the left pane.

G3.2 Create an operation

To perform a noise calculation in *AEDT*, the tracks and profile information need to be brought together through creating an operation. In the aircraft actions ribbon in the operations tab, create a new overflight aircraft operation by going through the prompts.

In the case of creating a helicopter overflight, it is not possible to do so using *AEDT 2d* due to a bug that overlooks overflight profiles for helicopters. This approach is therefore required as a temporary substitute. To resolve the bug issue, close *AEDT* and open *SQL SERVER MANAGEMENT STUDIO*.

G3.3 Customise tables with SQL

On the left pane under databases are all studies currently on the server. Expand the relevant study and following folders and lists:

Databases > "study name" > Tables > dbo.AIR_OPERATION

Databases > "study name" > Tables > dbo.FLT_ANP_HELICOPTER_PROFILES

In the two open tabs, the table displaying the recently created operation with profile will match approach in the helicopter profiles. In order to change the existing overflight operation to contain a flight profile, the following SQL query needs to be run.

```
SELECT [PROFILE_ID] FROM
[study_name].[dbo].[FLT_ANP_HELICOPTER_PROFILES] where HELO_ID =
'SA350D1' and OP_TYPE='V'
```

```
update [study_name].[dbo].[AIR_OPERATION] set [PROFILE_ID] = 100001,
[STAGE_LENGTH] = null where [AIR_OP_ID]=1
```

HELO_ID needs to refer to the helicopter profile containing the custom overflight profile and profile_ID needs to specifically match the code of the aforementioned profile which can be seen at the bottom of the second table- containing helicopter profiles.

Once the SQL query has been executed, the programme can be closed and *AEDT* reopened. Unfortunately, there will be no signs of any changes to the operation. Only once the noise metric calculation has been completed will there be evidence of the profile linking to the custom overflight.

G3.4 Create annualisation, receptor grid and set, and metric

In the operations tab of *AEDT,* a new annualisation needs to be created using the modified overflight operation. Essentially this process establishes a time window the model will calculate. By default it is a 24 hour period starting at the beginning of the day specified by the operation.

Following a complete annualisation, receptors need to be created in the definitions tab. As a test, the receptor resolution does not need to be high- 100m x 100m spacing is adequate. The x,y coordinates refer to the point of origin, which is the location of the first airport imported in the study. The receptors will then span out north and east of the origin point. An example receptor grid can be seen opposite. Once this is saved, a receptor set needs to be created using the neighbouring button in the ribbon. Name the grid and drag over the receptor grid. Once the annualisation, receptor grid and set have been created, one last step remains to produce a noise metric calculation.

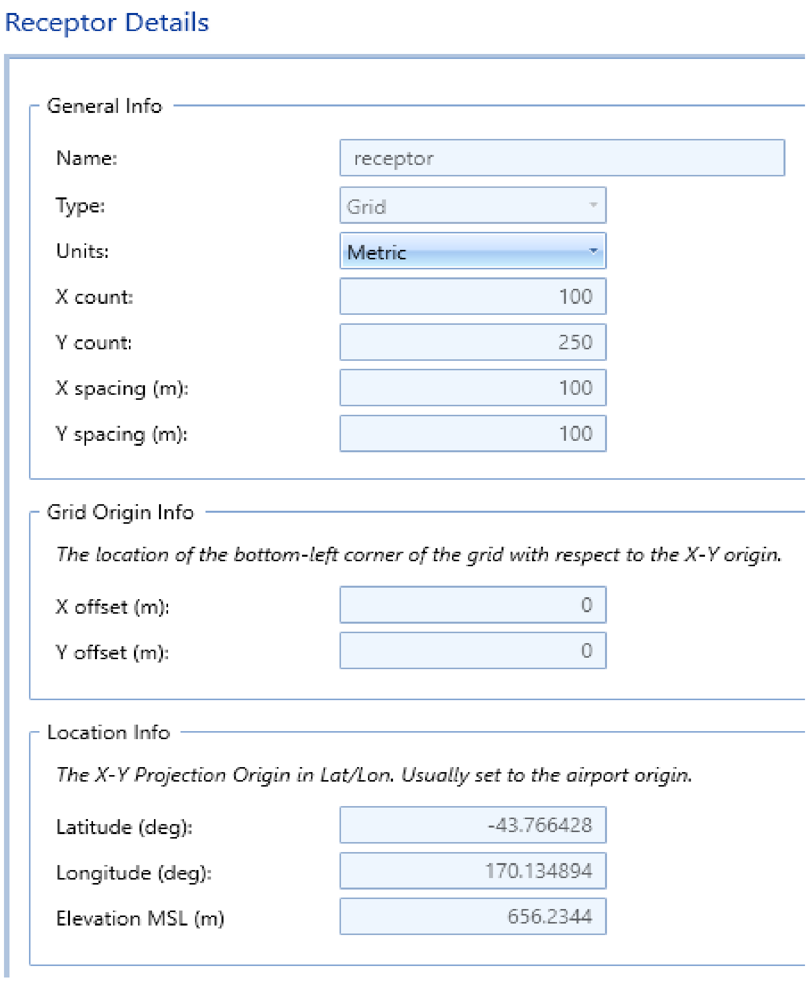

Figure 2: Example of a receptor set

G3.5 Terrain

To incorporate terrain in the metric calculation, a digital ground model (DGM) is required in float format (.flt) in WGS 84 projection. A DGM that covers the area of both Westland and Aoraki Mt Cook national parks can be found in the following directory:

W:\Acoustics\JOB FILES\A to H\DEBT of CONSERVATION\JOHANN KISSICK WORK\Templates

AEDT does not require the DGM to be imported, instead the folder it sits in needs to be referred to. In the definitions tab, select terrain and ambient and then edit to insert the same link to the folder. Then when preparing a metric in the 'set processing options' stage of the floating window, check the box indicating 'use terrain data'.